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Possible Humanistic Aspects of Science

By SIDNEY G. HACKER

Prefatory Note: A word of explanation is in order regarding the following remarks and their appearance in this journal. Last winter the writer suggested to some ten or twelve of his colleagues on the staff of The State College of Washington who are engaged in the study and teaching of the several branches of the humanities and the sciences that we might meet informally to discuss the question of the humanistic aspects of science. The suggestion was so well received and so many other people, hearing incidentally of the plan, expressed their interest in the idea that it was decided to extend a general invitation to anyone interested. Altogether there were ten meetings at each of which one staff member from one of the departments of the humanities or the sciences spoke. Each lecture was followed by a general discussion which, as it turned out, was always quite lively and interesting. The meetings were all well attended, by faculty, graduate students, and a few undergraduates from many diverse fields of study. The lectures were mimeographed subsequent to the lectures for general distribution to the audience. In addition Mr. D. N. Lowe, Secretary of the British Association for the Advancement of Science, and the authors concerned kindly gave permission to mimeograph for limited distribution the lectures of Professors Sir John L. Myres, R. V. Southwell, and W. E. le Gros Clark which were among those delivered to the conference on "Science as a Humanity" which was part of the Conferences on "The Advancement of Science" held by the British Association in 1941-3, as reported in Volume 2 of *The Advancement of Science* (to which name that of the famous annual *Reports* was changed in 1939).

In writing a note to Professor C. H. Gingrich I took the occasion to enclose a mimeographed copy of my remarks which were made at the first of these colloquia. Professor Gingrich very kindly suggested that certain parts might be of interest to some of the readers of this journal.

The essential thing about our colloquia is, I think, that together we found some meaning in the general problem of the possible humanistic aspects of science and received considerable pleasure and profit from discussing it. And if it should happen that this experience of ours might suggest a similar discussion of the subject among the staff of some other institution, perhaps the appearance here of the admittedly disjointed remarks which follow will have something of a justification.

In seeking to discuss the possible humanistic aspects of science, you

will expect of me, first of all, two definitions: What is a humanity? What is science?

I do not wish to avoid the issue, but both questions are extremely difficult to answer adequately. In either case an entirely satisfactory definition would take us down through dimly lighted caverns, perhaps "measureless to man," to the very foundation of the theory of knowledge itself. Less penetrating definitions are apt to be superficial and liable to be useless and even misleading. It would be most helpful and satisfactory if we could attack our problem in a strictly logical way. I confess to being unable to do this.

What is a Humanity?

I cannot answer this question directly, but can only approach it obliquely. Humanism itself is Janus-like, looking east and west. It looks back as reason's revolt against the dogmatism of tradition and the despotism of caprice. It looks forward to the emancipation of men's minds and souls, with a view to revealing to men the multitude of ways in which each man may seek, from within, for himself, the kingdom of God.

Perhaps a hint of a possible answer to the question of what is a humanity is implied in Peer Gynt's riddle and Solveig's answer. Badly cast button that he is, Peer has at last returned to search frantically and vainly, back and forth across the heath, for the button's loop, that is, for his real Self. Finally he confronts Solveig who stands, Penelope like, at the threshold of her own hut. Peer cries out to her in desperation,

> "Where was I, as myself, as the whole man, the true man?
> Where was I, with God's sigil upon my brow?"

It is well-known that in Solveig's answer Ibsen was reiterating his often expressed conviction of faith in the saving grace of womankind. But Solveig's answer is, I think, also the reply of the humanist:

"In my faith, in my hope, in my love."

The humanities are concerned with the moral and intellectual well-being of man. This does not mean man anatomized in medical or restricted in legalistic language. Rather it is concerned with the interplay of man with his fellowman and of man with the spiritual and temporal forces of the many environments of which he should be consciously aware.

What is Science?

This is a question of great difficulty, and I do not believe there is any one answer on which either scientists or philosophers would unanimously agree.

Science, most of them will say, is in some way concerned with *reality*.

And so one might begin by asking, what is "reality"? Professor Sir Edmund Whittaker[1] in his 1947 Tarner Lectures at Cambridge pursued the following line of attack. First, he sets forth a *provisional* definition of reality: ". . . *provisional*, because while the definition puts us in

contact with reality, it is not exhaustive . . .: *any factor which is the same for all percipients will be said to belong to reality.* Thus a first approach to the notion of reality is obtained by means of the factorization of experience."

He next asserts that ". . . the constituents of reality are not a mere confused inchoate multiplicity of things, but . . . *they can be correlated and recognized as forming an interconnected system, possessing an intelligible structure.* . . Physical reality thus includes, for instance, a particular crystal of Iceland spar, and it also includes the mathematical-physical-chemical theory which is common to all crystals of Iceland spar—their formation by the chemical union of calcium, carbon, and oxygen, their type of crystal-structure, their properties with regard to double refraction and polarization of light, and so forth. We say that the individual existent crystal is a *particular* while the concept of Iceland spar is a *universal. Scientific theories relate to universals.*"

With due regard to the difficulties involved it seems to me that this definition of reality, although I certainly know of none better, comes rather close to a perilous brink at which Professor Herbert Dingle, astrophysicist and philosopher, hesitated a few years ago.

I refer to the definitions which Professor Dingle employed in 1931 in his book "Science and Human Experience"[2] and which he subsequently sought to modify and revise in 1937 in his book "Through Science to Philosophy"[3] from which we quote below. In Professor Dingle's opinion—at least that of 1931—"Science can properly be characterized as the rational correlation of experiences common to all normal people, *if one is willing to accept normal people as already given.* . ." He also states that "the subject-matter of every science generally acknowledged to be properly so-called . . . consists of experiences on which normal people are agreed, and every non-science is concerned with experiences on which normal people are not agreed. . ."

To this kind of argument there is a sort of "gegenbeispiel," a contrary example. Professor Henry Norris Russell, the celebrated astronomer, called attention to the substance

Para—ethoxy—phenyl—thio—carbamide

which to some "normal" people is extremely bitter but to others is absolutely tasteless. There is no graduation of taste whatever: it is either very bitter or it is tasteless, and the number of people experiencing the one sensation is approximately that experiencing the other. Here is an experience which is certainly real but which is no factor common to all percipients. Nevertheless, as Professor Dingle says, it "appears to be a fit matter for scientific investigation . . ." and it is ". . . probably connected with some physiological differences between people . . ."

Professor Dingle looked for a way out of this impasse. He says: "My own introduction to this substance took place at a dinner of the Physical Society [of London] at the conclusion of which it was passed round the table, and the two classes of people appeared, as usual, to be

about equally represented. Some one (I think Sir William Bragg) suggested that only the good-looking ones experienced the bitter taste, and I quite agreed with him, although about half the gathering dissented. But there was a truth in this kind of comment which perhaps was not intended. The difference, I think, was actually of the same character as the differences in our appreciation of beauty, and neither will become scientifically significant until it can be correlated with physiological or other experiences which are common."

I am somewhat at a loss with this argument. But let us accept provisionally Professor Whittaker's definitions of reality and of "universals" and his statement that "Scientific theories relate to universals."

I have said elsewhere[4] that, in science, experiment and observation are fundamental, as everyone recognizes, but that "there must be more to science than the painstaking recording of observations and the scrupulous acknowledgment of error. A purely taxonomic account of the world with the sole aim of systematically enumerating, cataloguing, and classifying observations would lead to knowledge without understanding. The facts of observation must be interpreted, coordinated, and compared. To paraphrase Arnold's celebrated dictum (on the vision of Sophocles) science must seek to see the world clearly and also to see it whole. . .

"Science is not a mere collection of observations, but, on these as both the foundation and the structural framework, to which all else must be secured, is an edifice of interpretative and inferential ideas, under constant repair and construction. These ideas are the products of a transmutation effected by the human mind, wherein sight, by the magic alchemy of thought, becomes insight."

The Importance of Ideas

This brings me to what I consider the crux of the whole matter—of science and the humanities and a possible relation between the two: the essential significance of ideas.

No subject of human experience—scientific, artistic, whatever you wish—is more than a "tinkling of the camel bell" unless it involves an Idea.

One evening a few months ago at a meeting of an informal club to which Professor Albert W. Thompson and I have the pleasure of belonging, I quoted Samuel Johnson to the effect that dexterity is nothing but brute instinct. Professor Thompson said immediately, "It may be brute work!" But brute instinct or brute work, one will agree that neither can produce by itself alone a masterpiece of literature or art or science.

I am cognizant of the fact, for example, that A. E. Housman[5] had "trouble with the fourth stanza of the last poem in his first volume" and that he had to turn to and compose it himself, which he found "a laborious business." But the majority of the time as he strolled along after luncheon there flowed into his mind "with sudden and unaccount-

able emotion, sometimes a line or two of verse, sometimes a whole stanza at once, accompanied, not preceded, by a vague notion of the poem which they were destined to form part of. . ."

The psychology of invention and discovery in the scientific field would not be far different. After weeks of despairing futility, did not the whole theory of Fuchsian functions spring full-grown from Poincaré's mind as he was stepping on a pleasure bus in Paris? The psychology of invention and discovery in the mathematical field has been carefully examined by Professor Hadamard.[6] In science too there is the not infrequent experience of, as I believe Leibniz said, finding more guidance in the point of one's pencil than in one's own mind. But if this is the experience, as say when Planck discovered his radiation law as "merely an interpolation formula found by happy guess-work," there comes the necessary inescapable interpretation which is to give the result meaning. In Planck's case, there was the revolutionary idea of the quantization of energy, which horrified Boltzmann but which changed the face of physics and of world politics.

The most transcendent thing of all is the Idea of an idea.

There is, of course, the vital importance of the realization of an idea.

In order to be concrete let me say something, as an example, regarding the marvelous modern high-speed completely automatic computers and of the ideas of the man who first inspired them.

The Ideas of Charles Babbage and their Realization

In 1812 the English mathematician Charles Babbage embarked, with great vision and high hope, upon the making of a calculating machine which was in his words "to perform the whole operation . . . of both the computation and the printing of results . . . without any mental attention when once the given numbers have been put into the machine." This "Difference Engine" of Babbage's was not however to be a multipurpose machine, for the sequence of operations which it was to perform was to be of particular standard type.

Babbage resigned the famous Lucasian professorship of mathematics at Cambridge University[7]—a chair which Newton himself had held—in order to give all his time and energy to the construction of this machine. He invested, and lost, his own not inconsiderable personal fortune in it. In 1823, after he had constructed a preliminary model capable of printing columns of 6-digit numbers together with the first and second differences of these, the British government gave him a substantial subvention for the construction of the machine employing 26 significant figures and printing successive differences out to the sixth. But by 1833 the government abandoned its interest when it became clear that Babbage was unable to complete the machine.

In 1834 George Scheutz, a Swedish printer, inspired by Babbage's work did succeed in building such a difference engine using 16-digit figures and capable of calculating differences to the fourth order. It was exhibited in England in 1854 and at the Paris Exposition of 1855, and

subsequently was acquired by the Dudley Observatory in Albany, New York.

In this connection it may be said in passing that the needs for which Babbage had designed his "Difference Engine" are now satisfactorily met by many of the (semi-automatic) desk calculators and in particular, thanks to the researches of L. J. Comrie,[8] by certain commercial ledger-posting machines.

Before he had publicly abandoned the making of the "Difference Engine," Babbage had commenced work on an even more ambitious type of machine. This was his "Analytical Engine." It was intended to be completely automatic in the sense that it was to require only the initial intervention of the operator, who merely had to order the machine to execute a whole series of arithmetical operations in accordance with a detailed list of instructions. Without further counsel the machine was to execute these commands in complete detail—merely giving a signal if it ran into trouble or if upon examination it found certain of the commands to be arithmetically contradictory. Babbage never completed this great undertaking and only succeeded in assembling a small part of it shortly before his death in 1871.

Sophus Lie, the great Norwegian mathematician, was once asked what it took to be a good mathematician. He replied, "Imagination (Phantasie), Energy, Self-confidence, and Self-criticism." These four may be considered prerequisites for success in any profession, but there are of course other things required. Babbage lacked, in common parlance, the engineering "know-how," and had to rely on the technical skills and judgments of craftsmen, but primarily he lacked the necessary precision tools.

How was this "Analytical Engine" which Babbage began in 1833 to operate? It was to consist of three distinct fundamental parts: a "Jacquard apparatus," "a store," and a "mill," and there was to be an attached device for printing the results. The "store" was to consist of a large number of vertical columns of circular disks each marked with 0, 1, . . ., 9. These were not to perform any arithmetical operations but were merely passive storage devices. Babbage intended to have a thousand such columns each with fifty wheels, so that the "store" could be a register for a thousand fifty-digit numbers. The "mill" was to be an automatic calculating device which could do addition, subtraction, multiplication, and division. It was the part of the whole machine which exclusively was to do all the actual reckoning. The "Jacquard apparatus" consisted of two decks of cards, just such punched cards as the French weavers employed in controlling their looms for the reproduction of given designs. One deck was made up of "directive cards" and these were marked in one-to-one correspondence with the columns of the store. These directive cards were to be used merely to transport the numbers from the store to the mill and finally from the mill back to the store or to an automatic "printer." The second deck of cards consisted of

"operative cards" and they were only four in number, corresponding to the four arithmetical operations of addition, subtraction, multiplication, and division. These were used in the mill, ordering it to operate as indicated by the card.

Babbage's ideas make sense. Only the mechanical realization of his magnificent idea was required. When he died he bequeathed all his tools, parts, drawings, and something of his enthusiasm to his youngest son, Major-General H. P. Babbage, who after his retirement from the Indian Service in 1874 spent five years and considerable money on the project. After a short interval he again returned to it and in the three decades between 1880 and 1910 succeeded in perfecting certain parts of the machine. In April, 1910, H. P. Babbage exhibited a part of the machine at a meeting of the Royal Astronomical Society, displaying the machine's computation and printing of the first 44 multiples of π where the value of $\pi = 3.14159\ldots$ was given to 29 figures.[9] Unfortunately there was an error in the value of π which had been given to the machine and also (because of the weakness of certain springs) the machine made errors in the printing of the multiples 8π, 9π, and 11π.

When one speaks of the remarkable modern machines which today have seen all of Babbage's dreams come true it is well to remember the implications of this incident. Erroneous first impressions are equally disastrous to a machine and to the human mind. But whereas the latter can profit from experience—hard work, and things done well and things done badly—the machine cannot. The human mind has a divine magic all its own. As the late Mr. Justice Cardoza said, "Whatever goes out of one as effort comes back to him as ability: the alchemy never fails." A machine expends energy with no profit whatever to itself.

The Babbage project has been resumed within recent years, undertaken with improvements in design, modern high precision tooling, and modern electrical gear. The first direct descendant of the Babbage "Analytical Engine" is the great "IBM-Automatic Sequence Controlled Calculator" (ASCC) at Harvard University, completed in 1944.[10] The "store," to use the Babbage terminology, consists of 72 electro-mechanical adding-storage registers each capable of recording 23-digit figures (together with the proper algebraic sign + or —). The "Jacquard apparatus" is a continuous manually perforated paper tape which conveys both the "directive" and "operative" instructions to the central multiplying and dividing unit, which is Babbage's "mill." Electrical contacts are made through these punched holes, in turn exciting electro-mechanical relays. The final printing problem is done by an electric typewriter. In 1945 the Moore School of Electrical Engineering of the University of Pennsylvania completed a remarkable electronic computer which utilizes vacuum tube relays. This machine which is called the "Electronic Numerical Integrator and Calculator" or, now universally, simply the ENIAC, was the first multi-purpose completely electronic calculating machine.[11] It can add or subtract two ten-digit numbers in 0.0002

second (0.2 millisecond) or multiply two ten-digit numbers in 3 milliseconds.

Not only are these modern "Analytical Engines" capable of these fantastic speeds of reckoning but they have very extensive "memories" (storage of data, tables of sines, logarithms, etc.), and can both memorize and recollect these data at high speeds.

The only thing which these machines lack is Imagination of their own.

It would not be impossible to make a machine which would translate say German into English. But the translation would never be, could never be, anything more than literal. The machine might be capable of translating even certain idiomatic expressions, but it must necessarily miss entirely the nuances of meaning. A machine could be made to turn out rhymes and limericks for every conceivable radio advertising stunt, but no machine can be made to produce poetry.

Astronomy as a Science and a Humanity

It is common misunderstanding that the telescope reveals to man his insignificance in the vast physical universe about him. Indeed it is man's essentially significant role in the world which the telescope reveals to him.

After all it is man who has weighed the earth, the planets, and the sun and the other stars. It is he who has measured their distances and analyzed their motions. He has measured the intrinsic brightness of the stars and has found both theoretically and observationally, to his great surprise, that the luminosity of a star is proportional to its mass. Man has read and interpreted the spectra of the meteors, the comets, the stars, and the obscuring dust and incandescent gases scattered in the great space between the stars of our own Milky Way system, and the galaxies in space far out beyond our own. In so doing he has found within the last two decades the proof of the great law of modern astrophysics: materially the universe is one. Everywhere we find the same elements and in roughly the same proportions. To paraphrase the words of Edmund Burke, the question of course is not this stubborn spirit, but what in heaven's name are we to do with it.

The temperatures of the atmospheres of the stars have been determined by various and consistent means. These surface temperatures range from some 2,000° C continually upwards to 100,000° C. There is thereby provided an immediately available laboratory for the study of matter under high temperature conditions beginning at just the place where terrestrial ovens are reaching their maxima. In the combined attack in the physical laboratories on the one hand and in the astronomical observatories on the other, the behavior and properties of elementary matter can be studied under the wide temperature conditions from near absolute zero to 100,000° C. In fact, it is under the conditions which prevail in the stellar atmospheres that we learn a great deal about the fundamental properties of matter. For example, the spectrum of iron is

much richer in the atmosphere of the sun, and that of titanium is much richer in the spectrum of Arcturus, than in spectra obtained in terrestrial laboratories, for we find the faint "predicted" spectral lines which modern physical theory anticipates.

There is properly much concern these days with the "atomic" bomb. However, it is not often appreciated that when we look up at the stars at night we see objects which operate and have operated for thousands of millions of years on precisely the same principles. It was the discovery of modern astrophysics (due to Professor H. Bethe of Cornell primarily, 1939) in conjunction with the knowledge gained from the study of matter in the cyclotrons of the laboratories that the sun's heat and light which sustain us are the result of a magnificent cyclic transmutation of matter capable of continuous repetition with a relatively slow diminution of the mass which composes the sun. Of this cyclic six-step carbon-nitrogen-oxygen transmutation, four steps have actually been observed in the laboratory. Carbon acts as the catalyst, entering the reaction and helping it to occur but in the end itself returning unchanged.

The man in the street may take to heart the transcendent aspects of science, for they touch directly on his every-day existence. For one example, annually there are several so-called meteor showers, the dates of which are well known. We know, thanks to the work of A. M. Skellett (1934) and others, that the meteors entering the earth's atmosphere from outer space substantially effect the ionization of the earth's upper atmosphere. The Kennelly-Heaviside "ceiling," by which commercial short wave-length radio waves are reflected back to earth, will be seriously affected during the period (from a few to many hours) of these meteor showers. Short-wave radio communication will be very poor at the times of these showers. If at one of these times we should put in a call to London to find out the latest news of concern, we might very likely be well advised to postpone the call, if practicable, for a few hours until the effects of the meteor shower are past and the reception of radio signals has improved.

Every night the triangulation cameras of the Harvard Observatory, under the general direction of Professor F. L. Whipple, are continuously photographing the meteor trails, which are incandescent streaks in the earth's atmosphere, excited to brilliance by these smallish particles traveling at an average velocity (v) of some 26 miles a second. Although the average mass (m) of these meteors is small, the energy generated ($mv^2/2$) is tremendous; a one-gram meteor generates 200,000 calories of heat at this velocity, whereas the finest coal generates only 8,000 calories per gram. Perhaps a thousand million meteors on the average enter the earth's atmosphere every day. All but a very few of the largest are consumed in the atmosphere before they ever reach the earth's surface. The photographic plates of these meteor trails are carefully measured at the Harvard Observatory and from their analysis

we not only learn things of astronomical importance about meteors and the earth's upper atmosphere, but also something of the ballistics of high-speed projectiles at great altitudes.

Mathematics and Art

There is an artistic aspect of science to which I should like to refer. To illustrate this I shall choose for example the "purest" of the sciences, mathematics.

Just as the writer of a book needs readers, as Holbrook Jackson wrote a book[12] to say, an artist needs someone to look at his paintings. Of course, like a certain school of philosophers will assure us about the physical world, a painting can exist without a single person to see it, except, perhaps, the painter.

I recall having admired at one of the recent exhibitions by the members of the Fine Arts department a most attractive painting by our own Professor Worth D. Griffin, and when I stepped closer to see the name which he had given to his painting, even though acquainted with his fine sense of humor, I was unprepared for the title "You Don't Think So?".

Nevertheless I believe the writer and the artist would appreciate, and in fact need, an audience, and in particular one which is well informed.

Mathematics certainly has progressed with a very limited audience comprised almost entirely of its own devotees, and in fact with a somewhat over-awed and not altogether sympathetic public. But there are beautiful mathematical gems which should be "seen" by every educated person. I think that once understood, these theorems are as beautiful as a painting or poem. Indeed just as a particular poem can definitely appeal to a man at particular times, so these theorems can come to mind on occasion to cheer his spirits and excite his imagination.

Let us give an example. The name of Euclid which is usually associated with geometry is also attached to certain wonderful theorems in what the Greeks called arithmetic, from their word for "number," but which today we call the theory of numbers in order to avoid a crass misunderstanding. The marks by which we count happen to be the Hindu-Arabic symbols 1, 2, 3, . . . This is a remarkable system employing not only a practically convenient base but the superlative mathematical notions of zero and of place-value; but these features need not concern us. In fact it is only to be understood that the following is independent of the particular marks which we choose to use. Certain of these marks are "primes," that is, divisible only by themselves and unity; thus 2 is the only even prime. The rest are composite numbers which are made up of products of primes, in, as Euclid himself showed, one and only one way, except for the obvious trivial rearrangements of the orders of the factors. How many primes are there? Is the universe of primes finite or endless? This is the question Euclid set for himself. In the range between 1 and 1000 there are 168 primes; between 4000

and 5000, 119 primes; between 9,999,000 and 10,000,000, 53 primes; perhaps the primes eventually die out. Euclid's answer is that they do not.

In mathematics we make common use of the "Postulate of the Excluded Middle": of two mutually contradictory statements one is true and one is false. This postulate underlies the kind of indirect argument called "reductio ad absurdum." In order to establish positively a given proposition of a "yes or no" character, we assume the contrary of the proposition and establish that this assumption results in an inherent contradiction.

Thus to prove Euclid's theorem that *the number of primes is endless,* we assume on the contrary that there are a finite number of primes. Hence we assume the existence of a last, or largest, prime. Call it L. The complete list of primes is accordingly 2, 3, 5, 7, 11, . . ., L. Let us now construct a number N defined by

$$N = (2 \times 3 \times 5 \times 7 \times 11 \times \ldots \times L) + 1.$$

But N is not divisible by any one of the primes 2, 3, . . ., L, for division of N by one of these leaves a remainder, by virtue of the 1 added to the product in N. Hence we have found a number, namely N, which is either itself a prime or is a non-prime divisible by some prime larger than L. In either event there is a prime greater than L, which was assumed to be the largest prime. Hence the assumption is false and the theorem is true: the number of primes is endless.

There are many other beautiful examples of mathematics which like this are of great color, luster, and depth. I have sought in another place to explain this more fully from an elementary view point.[13]

In the symposium on "Science as a Humanity" held by the British Association for the Advancement of Science in 1943, the distinguished mathematical engineer R. V. Southwell said that he found the answer to the question "What is the cultural value of science?" not ". . . in its story of material achievement" but "rather in its development of a special kind of thinking." He accordingly urged "some acquaintance with scientific thought . . . in the education of 'normal citizens'."

A Fundamental Postulate

As you see, and no doubt have suspected from the beginning, I come to the end of these remarks without being able to approach this subject of the humanistic aspects of science in anything resembling what the strict logicians, and others, would regard as a satisfactory fashion. I have confessed even to inadequacy, frankly to inability, with respect to the basic definitions. But even so, perhaps I may be permitted to state at last what seems to me a fundamental postulate for the humanities, for science, for any discussion bearing on their interrelation, and in fact for all human endeavor. That postulate is this:

Man is for man a significant, essential, non-trivial element in the universe.

I believe that the really fundamental postulate is much broader than this and that the phrase "for man" is needless, but of this we have no direct knowledge, but only instinct, and, above all, faith.

References

[1] Whittaker, Sir E. T., "From Euclid to Eddington: A Study of Conceptions of the External World," (The Tarner Lectures, 1947), Cambridge Univ. Press, 1949, pp. 2-4.

[2] Dingle, Herbert, "Science and Human Experience," Williams and Norgate, London, 1931.

[3] Dingle, Herbert, "Through Science to Philosophy," Oxford Univ. Press, 1937, pp. 31-6.

[4] Hacker, S. G., "Aspects and Aspirations of Science: An Introductory Remark," *American Scientist*, **36**, 452, 1948.

[5] Housman, A. E., "The Name and Nature of Poetry" (The Leslie Stephen Lecture, 1933), Cambridge Univ. Press, 1933, pp. 48-50.

[6] Hadamard, Jacques, "The Psychology of Invention in the Mathematical Field," Princeton Univ. Press, 1945.

[7] An interesting account of "The Lucasian Professors at Cambridge" from Isaac Barrow (1664) to Joseph Larmor (1903-1932) will be found in *Nature*, **130**, 117, 1932.

[8] For an account of these one may consult, for example, the following articles by L. J. Comrie: "Recent Progress in Scientific Computation," *Journ. Sci. Inst.*, **21**, 129, 1944; "The Nautical Almanac Office Burroughs Machine," *Monthly Notices, R.A.S.*, **92**, 523, 1932.

[9] Cf. *Monthly Notices, R.A.S.*, **70**, 517 and 645, 1910.

[10] A complete description of the calculator is given by H. H. Aiken, *et al*, in *A Manual of Operation for the Automatic Sequence Controlled Calculator, Annals of the Computation Laboratory of Harvard University*, **1**, Harvard Univ. Press, 1946. The following series of three papers by Professor Aiken and Miss Grace M. Hopper are not only of general interest but also provide an excellent introduction to the study of the "Manual": *Electrical Engineering*, **65**, 1946, (1) pp. 384-391, (2) pp. 449-454, (3) pp. 522-528.

[11] The ENIAC is described in his inaugural lecture by D. R. Hartree, "Calculating Machines: Recent and Prospective Developments and their Impact on Mathematical Physics," Cambridge Univ. Press, 1947.

[12] Jackson, Holbrook, "The Reading of Books," Charles Scribner's Sons, N. Y., 1947.

[13] Hacker, S. G., "Arithmetical View Points: An Introduction to Mathematical Thinking," State College of Washington, 1948.

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Long-Focus Photographic Astrometry

By PETER VAN DE KAMP

(Continued from page 191)

CHAPTER VI

Unresolved Astrometric Binaries

1. *General formulae for proper motion, parallax, and orbital motion.*

The analysis for parallax, orbital motion, and proper motion given in Chapter V is applicable in the case where all elements of the (photocentric) orbital motion are known except the scale a. In order to arrive at formulae of more general applicability we write the orbital effects as follows:[1,2]

$$\begin{aligned} aQ_a &= a(b)x + a(g)y = (B)x + (G)y \\ aQ_b &= a(a)x + a(f)y = (A)x + (F)y. \end{aligned} \tag{1}$$

The dynamical elements P, e, and T are represented by the elliptical rectangular coordinates x and y in the unit orbit.[3] The geometric elements (B), (A), (G), and (F) refer to the observed photocentric orbit of the unresolved system. They are related to the orientation factors[4] and to the Thiele-Innes constants [5,6] as follows:

$$\begin{aligned} (B) &= a(b) = -(a/a)\,B \\ (A) &= a(a) = -(a/a)\,A \\ (G) &= a(g) = -(a/a)\,G \\ (F) &= a(f) = -(a/a)\,F. \end{aligned} \tag{2}$$

We recall that a and a are the semi-axes major of the photocentric and relative orbits and that

$$a = (B - \beta)\,a, \tag{3}$$

where B and β are the mass and luminosity of the companion in terms of the combined primary and companion. Experience with blended exposures of known binaries has commonly failed to reveal any elongation of images for separations up to 1″ or even more, and for magnitude differences as small as two, for which β is as high as .14; for smaller separations even binaries with smaller magnitude differences may go undetected on photographic plates.[7,8]

A close companion may be too faint to be detected visually or spectroscopically, but affects the center of light by pulling it toward the barycenter. The photocentric orbit of the unresolved binary generally is smaller than the orbit of the primary. Only in the case of a comparatively luminous companion of very low mass, it could happen that the photocentric orbit is larger than that of the primary (Section 4). In the case that the companion is truly dark or when its image is not

blended with that of the primary, the measured positions refer to the primary and β is zero.

The general formulae for analyzing the positions of the photocenter for proper motion, parallactic, and orbital motion are therefore

$$\begin{aligned} X &= c_x + \mu_x t + \pi P_\alpha + (B)x + (G)y \\ Y &= c_y + \mu_y t + \pi P_\delta + (A)x + (F)y. \end{aligned} \tag{4}$$

These formulae are useful if the dynamical elements are known, for example, from spectroscopic information. They are very suitable if nothing whatsoever is known about the orbital elements. This is the case, *par excellence*, resulting from the discovery and subsequent study of an astrometric binary revealed by variable proper motion. First the observed positions are corrected for provisional values of proper motion and parallax, in the hope that the adopted proper motion is as close as possible to that of the barycenter. The remainders are then analyzed for orbital motion;[7,8] successive approximations are generally necessary. The corresponding analysis for an unresolved binary component of a visual binary[9] was mentioned in Chapter II.

2. *Orbital analysis.*

The dynamical elements may be determined by Zwiers' method,[10,11] which in this case involves locating the invisible focus or barycenter. This procedure may be awkward and a different method therefore commends itself. Instead of the apparent orbit, we study its projection on any coordinate, right ascension or declination or any other direction. This procedure has been used for "linear" orbits as they are represented by all spectroscopic binaries, and by certain visual orbits seen edgewise. However, the principle of the method is also applicable to any "open" visual or photocentric orbit.[12,13]

The advantage of using displacements (and velocities) plotted against the time is that the best known observed datum, the time, enters explicitly. Periastron and apastron are located by the fact that their mean anomalies differ by 180° and their ordinates are equal and opposite when referred to the center of the orbit. Periastron and apastron are conveniently located by making a copy of the displacement curve, reversing it along the central line representing the center of the orbit and shifting the reversed curve half a period along the time axis. Generally two pairs of intersections result, of which the single intersection on the shorter, steeper, branch, and the central intersection on the longer branch, represent periaston and apastron, respectively.

The slopes of any displacement curve represent projected velocities. The ratio of the true velocity vectors at periastron and apastron is $-(1+e)/(1-e)$, their directions being opposite. Since this ratio remains the same in projection, the ratio of the slopes at periastron and apastron amounts to $-(1+e)/(1-e)$, for any displacement curve, including those of astrometric orbits perpendicular to the line of sight. We thus can not only distinguish periastron from apastron but also

derive the eccentricity of the orbit, independently of the focus. The method becomes unreliable when periastron and apastron are close to the extreme amplitudes; this occurs if the major axis is at a small angle with the line of nodes,—for any spectroscopic orbit and for any astrometric orbit with a high inclination. In this case other methods are used.[12]

With the set of dynamical elements P, c, and T thus obtained, x and y are computed and the observations represented by the general formulae (4). An analysis of the equations yields the four geometric elements, (B), (A), (G), and (F), from which the scale a and the three orientational elements Ω, ω, and i may be computed. Generally it will be necessary and advisable to use successive approximations and introduce variations in the set of dynamical elements in order to test the stability of the results. While it is possible to solve simultaneously for differential corrections to all orbital elements, such procedure is hardly warranted at the current stage of this problem. The process of variations is certainly to be preferred and has the great advantage of remaining in close touch with the real worth of the available material.

3. *General considerations.*

The astrometric study of photographically unresolved binaries consists of two parts: (1) to establish the existence of deviations, which cannot be accounted for by proper motion and parallax, (2) to determine the photocentric orbit from these deviations. While it may be relatively simple to detect initial deviations, the second step is much more difficult.

Thousands of parallax determinations of "single" stars have been made and, with few exceptions, it has always been possible to represent the observed positions satisfactorily by proper motion and a parallactic orbit of appropriate size. Moreover, no increase in the probable error of unit weight has been found for stars of large parallax.[14] This general absence of observable orbital motion may often be due to a negligible value of the semi-axis major of the photocentric orbit. For example, a is zero if both components have the same mass and luminosity. However, even with an appreciable value of a, orbital motion may not be found because of the small number of plates, 20 or 30, and short time interval, often two years only, employed in conventional parallax determinations. If the period is short, the amplitude of the photocentric orbit may be too small to be detected. If the period is long, more time is required to detect orbital motion. Moreover, the orbital motion may be partly absorbed in the parallactic and in the proper motions, or it may be temporarily or accidentally disguised through gaps in the series of observations. The conventional parallax determinations generally are neither suitable for the discovery of orbital motion nor affected by any existing orbital motion.

For any thorough investigation it is desirable to go beyond the extent and also beyond the occasional repetition of conventional parallax series.

A steady continuation of observations for an interval of over, say, twenty years is usually desirable; with the continued addition of plates the weight of a determination of a uniform acceleration increases with the fifth power of the time interval. Even so, the discovery chances depend on the particular portion of the orbit in which the star happens to be. Even for shorter periods a prolonged series is desirable and necessary because of otherwise incomplete coverage of the orbit. There are, above all, the annual gaps of at least six or seven months imposed by the narrow hour-angle requirements of the observations. In any case, plates should be taken without particular regard to parallax factor so as to ensure as even a distribution in time as possible under these circumstances. Because of the recurring annual gaps spurious periods must be guarded against; with the limited accuracy, scattered positions in successive cycles of a short-period orbit may be interpreted as an orbit with a long multiple period, unless plates are taken also in close temporal succession. As long as the binary is not resolved, the analysis lacks the control of the harmonic relation

$$a^3/P^2 = M_A + M_B, \tag{5}$$

which for resolved binaries may serve as a guide for the period. The criterion of Keplerian motion may not distinguish between different possible orbits, because of limited observational accuracy. There is also the danger of interpreting a limited, initial set of residuals by a fortuitous orbit, which, however, should be eliminated through continued observations.

A satisfactory orbit is generally not obtained until all phases of the orbit have been covered in a representative way and a second orbital cycle has definitely set in. A correct dynamical interpretation is aided by the fact that the Keplerian motion as a rule is observed in two coordinates. The blending (β) of the two components, and variability of either component, remain potential sources of error in any analysis for a photocentric orbit.

4. *Interpretation of the orbital elements. Mass function.*

From a dynamical standpoint the principal elements of an orbit are the semi-axis major a and the period P. For a resolved astrometric binary, the sum of the masses may thus be obtained from the harmonic relation (5) assuming the parallax to be known and using the conventional astronomical units. For an unresolved astrometric binary the information obtainable about the mass is limited to the mass function:

$$a^3/P^2 = (B - \beta)^3 (M_A + M_B), \tag{6}$$

$$\text{where } B = M_B/(M_A + M_B) \text{ and } \beta = 1/(1 + 10^{0.4\Delta m}). \tag{7}$$

Compare this with the mass function obtainable for the case of a spectroscopic binary with one spectrum visible:

$$B^3 \sin^3 i\,(M_A + M_B). \tag{8}$$

The above astrometric mass function is affected by the, generally un-

known, blend effect β; the spectroscopic mass function, always, by the unknown inclination i.

Thus a combined astrometric and spectroscopic study becomes significant in the case of appreciable inclination (of which eclipsing binaries form a favorable example), since the astrometric study furnishes the inclination i, while the spectroscopic study is probably not influenced by the blend effect β. In such a combined study the mass function $B^3 (M_A + M_B)$ and the ratio β/B may be determined. So long as the companion remains unseen, visually or spectroscopically, the masses of the components cannot be rigorously derived. With a reasonable assumption about $M_A + M_B$, however, a value for B, and hence β, can be found and corresponding values of M_A or M_B derived.

If, however, as is often the case, the astrometric information is not supplemented by spectroscopic data, we remain in the dark as to the evaluation of the luminosity correction β. Generally, therefore, we are confronted with the interpretation of the mass function (6) which contains the three unknowns M_A, M_B, and β. Instead of the mass function (6) we may write:

$$(B - \beta)(M_A + M_B) = \alpha P^{-2/3} (M_A + M_B)^{2/3} \qquad (9)$$

Note that the astrometric observations alone do not yield the sign of α; hence the above expressions (6) and (9) have the double sign. In order to interpret the observations, we generally make different assumptions of the sum of the masses $M_A + M_B$, which then will yield limiting values for the mass of the companion. If we take $B - \beta$ positive, we find the following limiting values for the masses of the components: upper limit primary: $M_A + \beta (M_A + M_B)$, lower limit companion: $M_B - \beta (M_A + M_B)$. If $B - \beta$ is negative, we find the following limiting values for the masses of the components: lower limit primary: $M_A - (1 - \beta)(M_A + M_B)$, upper limit companion: $M_B + (1 - \beta)(M_A + M_B)$. This means that without additional information, the absolute size of the photocentric orbit fails to distinguish between the two components.[15,16] A minimum value of the mass always is found for that component which is revealed as the perturbing influence on the photocenter, *i.e.*, the component which is on the side of the barycenter opposite the photocenter.

Often a choice between the alternate interpretations can be made by considering the implications of the results for mass and luminosity. The definition of primary and companion implies in all cases $0 < B < 1$ and $0 < \beta < .5$. Any admissible value of β may satisfy the condition $0 < B - \beta < 1$, in which case the photocentric orbit is always smaller than the orbit of the primary. The alternate interpretation is subject to the restriction that $0 < \beta - B < .5$. In this case the photocentric orbit may be larger than the orbit of the primary, *i.e.*, $\beta - B > B$ or, $\beta > 2B$, which implies a value of $B < .25$. Generally, however, the photocentric orbit is smaller than the orbit of the primary. Since the dimensions of the latter are a measure for the mass of the companion,

the observations give a lower limit for the mass of the companion. One has to be very careful, therefore, about ascribing a very small photocentric orbit to the influence of a planetary companion.

The accompanying table illustrates the interpretation of the mass function for the case $|B-\beta|=.2$.

Δm	β	$B-\beta=.2$ B	$\beta-B=.2$ B
0	.500	+.700	+.300
1	.285	+.485	+.085
2	.137	+.337	(−.063)
3	.060	+.260	(−.140)
.	.	.	.
.	.	.	.
.	.	.	.
∞	0	+.200	(−.200)

For the case $\beta - B = .2$, the value of β has to be larger than .2, *i.e.*, the companion may not be more than 1.5 magnitude fainter than the primary, since B must remain positive. Generally it has not been observed that such a small difference in magnitude goes together with such a large discrepancy in masses, and we therefore are inclined to assume that the $B - \beta$ solution has to be accepted and a corresponding choice made of possible B, β combinations. However, it is questionable in how far the known mass-luminosity relation for visible stars should be permitted to influence any choice. In no case can a rigorous interpretation be made till a relative visual orbit or a spectroscopic orbit of either or both components is observed.

5. *Applications.*

The red dwarf Ross 614 ($6^h\,24^m.3$, $-2°\,44'$, 1900; $11^m.3$, M2e, $\pi = ''.25$) is an excellent example of an unresolved astrometric binary, the first one to be discovered by photography.[1] The star has been observed at the McCormick Observatory since 1928, at the Sproul Observatory since 1937; the present study includes 309 Sproul plates. An analysis of photographic positions derived at both observatories leads to the values $a = 1.23$ a.u. and $P = 16^y.5$ for the photocentric orbit.

Since the binary has not been resolved visually, it is not likely that the companion is less than one magnitude fainter than the primary. Various considerations suggest, for example, the following possible dynamical interpretation: $M_A + M_B = .25\ \odot$, $\Delta m = \infty$; $M_A = .17\ \odot$, $M_B = .08\ \odot$.

Another example is Lalande 21185 ($10^h\,57^m.9$, $+36°\,38'$, 1900; $\pi = ''.41$). A recent study was made from 679 Sproul plates taken on 188 nights over the interval 1937-1950. An analysis of the photographic positions yields the values $a = .07$ a.u. and $P = 1^y.14$. The corresponding value for the lower limit of the companion mass is $.066\ (M_A + M_B)^{2/3}\ \odot$.

The apparent magnitude and spectrum of Lalande 21185 are 7.6 and M2, the absolute visual magnitude 10.7 and the absolute bolometric

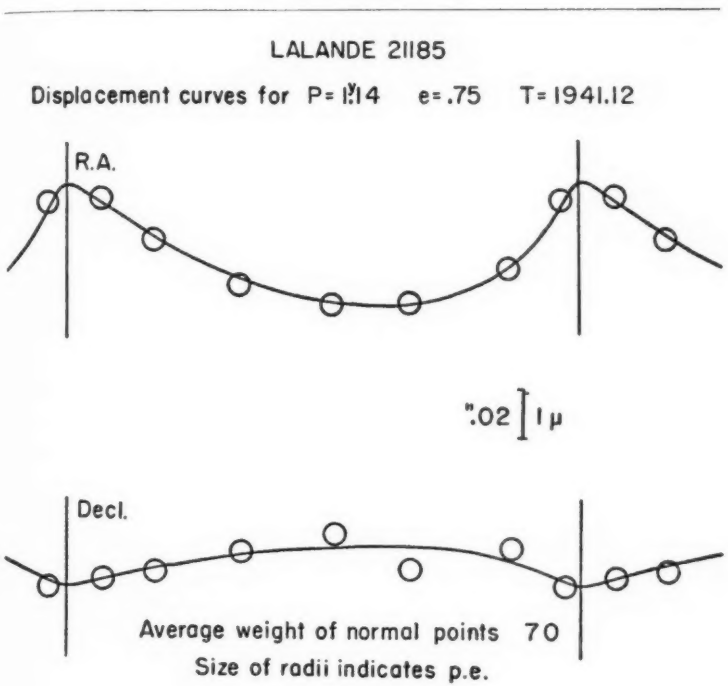

FIGURE 1
THE UNRESOLVED ASTROMETRIC BINARY LALANDE 21185.
DISPLACEMENT CURVES IN RIGHT ASCENSION AND DECLINATION.

magnitude 8.7. For assumed values of .25 ⊙ and .50 ⊙ for $M_A + M_B$ we obtain .03 ⊙ and .04 ⊙ as lower limits for M_B. If the fainter component is not completely dark but, say, two magnitudes fainter than the primary, the values for M_B would be .06 ⊙ and .11 ⊙, respectively. The companion has not yet been detected visually. We recall the theoretical statement by Russell that bodies of less than .05 times the sun's mass would not be astronomically observable by their own light.[17] At present the smallest mass determined for a visible star is that of the faint dwarf companion of Krüger 60, namely .14 ⊙.

Studies of unresolved astrometric binaries by long-focus methods are in progress at several observatories.

REFERENCES

[1] *Astr. Jour.*, **55**, 236, 1951.
[2] *Astr. Jour.*, **55**, 251, 1951.
[3] *Union Obs. Circ.*, No. 71, 1927.
[4] *Astr. Jour.*, **51**, 161, 1945.
[5] *Union Obs. Circ.*, No. 68, 354, 1926.
[6] *Bull. Astr. Inst. Neth.*, **3**, 149, 1926.
[7] *Publ. Astr. Soc. Pac.*, **55**, 263, 1943.

[8] *Astr. Jour.*, **51**, 7, 1944.
[9] *Astr. Jour.*, **51**, 12, 1944.
[10] *Astr. Nachr.*, **139**, 369, 1895.
[11] *Astr. Jour.*, **19**, 9, 1898.
[12] *Astr. Jour.*, **52**, 185, 1947.
[13] *Astr. Jour.*, **52**, 189, 1947.
[14] *Astr. Jour.*, **46**, 85, Table 3, 1937.
[15] *Astr. Jour.*, **53**, 47, 1947.
[16] *Astr. Jour.*, **53**, 207, 1948.
[17] *Astr. Jour.*, **51**, 13, 1944.

CHAPTER VII

Spectroscopic and Eclipsing Binaries. Perspective Acceleration.

In this final chapter we consider the application of the methods of long-focus photographic astrometry to miscellaneous problems, dealing with individual stars. First we review briefly a recent astrometric study of Algol. Next we discuss the provisional results for parallax and astrometric orbit of VV Cephei. Finally we present tentative results for the secular acceleration of Barnard's star.

1. *Apparent orbit of the binary Algol AB, C.*

Algol AB ($3^h\,1^m.7$, $+40°\,34'$, 1900) is the well-known eclipsing binary with a period of 2.867 days. The best established of the longer periods, first detected spectroscopically, is that of 1.873 years, attributed to the unseen companion Algol C.

Algol has been on the Sproul astrometric program since 1920. A solution based on 560 plates yields the very small value $''.015 \pm ''.003$ (p.e.) for the semi-axis major a, of the $1^r.873$ orbit of the photocenter of Algol AB and Algol C. The inclination of the orbit is found to be 63°. Photometric results of Eggen yield a value of .52 a.u. (astrometrical units) for the quantity B a sin i. With the aid of the Sproul value of i we find $Ba = .58$ a.u. Assuming 6 ⊙ for the combined mass of Algol AB, the mass of Algol C is found to be 1.45 ⊙; no conclusive evidence of the luminosity of Algol C is obtained.[1]

Numerous studies of the astrometric orbits of spectroscopic binaries have been made by Alden both at the McCormick and Yale Observatories.[2] A recent example of an orbital investigation, using astrometric and spectroscopic material, is Strand's study of Procyon.[3]

2. *Apparent orbit of the binary VV Cephei.*

An illustration will now be given of an astrometric study of a long-period, unresolved, eclipsing binary, for which both spectroscopic and photometric orbital information is available. The star is VV Cephei ($21^h\,53^m.8$, $+63°\,9'$, 1900), the visual magnitudes of the components are 4.9 and 5.6, the spectra gM2 and B. An early astrometric study was made several years ago.[4] The present study is based on 516 plates taken with the Sproul refractor over the eleven years 1938-1948. The results reported here are from an unpublished investigation; the analysis is tentative and the conclusions are provisional.

In the analysis of the measured positions the dynamical elements were taken from Goedicke's orbit:[5] $P = 20.4$ years, $e = .23$ and $T = 1942.553$. The inclination is found to be in the second quadrant, *i.e.*, the orbital motion is retrograde. If we adopt the inclination —110° (Goedicke), the geometric elements yield $a = ''.064$. This observed value for the semi-axis major of the photocentric orbit can now be related to the parallax as follows. Most of the photographs for this star were taken on Eastman C-plates (and No. 12 Wratten filter); for the effective wave length λ 5800, a ratio $l_A/l_B = 18$ is found from Goedicke's data for the relative intensities of the two components at λ 5800; a value of $\beta = .05$ has been adopted. The spectroscopic analysis yields 13.3 a.u. for the semi-axis major Ba of the orbit of the primary, and an estimated value of .41 for B. Hence the photocentric orbit would be in the ratio $(.41 - .05)/.41$ to the orbit of the primary, *i.e.*, 11.7 a.u. In other words $a = ''.064$ corresponds to 11.7 a.u., and thus we find a parallax of $+''.0054$. This value may be compared with the direct value $+''.0056 \pm ''.0029$ obtained from an analysis for relative parallax, or, reduced to absolute, $+''.0077$. The average of the two determinations therefore yields $+''.0065$ for the absolute parallax of VV Cephei.

Within another decade the star will have been followed through one complete cycle and a more thorough investigation will be in order. Meanwhile the present conclusions for VV Cephei, as well as those for Algol, may be considered encouraging and indicative of the kind of contribution which intensive astrometric observations may be expected to yield, for the apparent orbits of unresolved binaries which are also studied by methods spectroscopic, or photometric, or both.

3. *Secular perspective acceleration.*

On the assumption of constant space velocity and absolute magnitude, the following expressions exist for the first order term of the secular changes in the annual proper motion (μ) and parallax (π), the radial velocity (V), and the magnitude (m):

$$\text{yearly change in } \mu \;:\; -2''.05 \times 10^{-5}\,\mu\pi V \qquad (1)$$
$$\text{yearly change in } \pi \;:\; -1''.02 \times 10^{-5}\,\pi^2 V \qquad (2)$$
$$\text{yearly change in } V \;:\; +2.30 \times 10^{-5}\,\mu^2/\pi \text{ km/sec} \qquad (3)$$
$$\text{yearly change in } m \;:\; +2.22 \times 10^{-5}\,V\pi \text{ mag.} \qquad (4)$$

Here μ and π are expressed in seconds of arc per year, V in km/sec, and m in magnitudes.[6,7,8]

Our first interest lies in the secular change of the proper motion, the secular perspective acceleration. This quantity is small, but the accumulated effect increases with the square of the time and therefore becomes very significant as time goes on.

Attention has been drawn to the importance of using the observed secular acceleration (1) for deriving the radial velocity V independent of the Doppler shift. This procedure permits, in theory at least, a determination of the gravitational red shift by correcting the observed red

shift for the value of the radial velocity determined geometrically from the observed perspective acceleration, and the well-known values of the proper motion and parallax.[9,10]

In practice the situation is not favorable, since the secular change in the proper motion, and also in the parallax, are irrevocably tied up with apparent secular changes caused by the reference stars.[11,12,13] Both the reductions from relative to absolute proper motion and parallax are subject to secular changes caused by the proper motions and parallaxes of stars. We recall that the plate-reduction of a measured position may be written as follows:

$$X = [Dx_s] + X' - [Dx'], \tag{5}$$

limiting ourselves to one coordinate. Here X' and x' represent the measured positions of central and reference stars. Full plate-constant reduction is insured by sufficiently often changing the dependences; hence the measured positions x' may be assumed to have been made in the coordinate system defined by the positions x_o of the reference stars at an arbitrary zero epoch. Hence, in the usual notation:

$$x' = x_o + \mu_x t + \pi P_a. \tag{6}$$

Ideally, we should like to have a reference system (x_o) which had neither proper motion nor parallax, in which case the plate reduction would be

$$X = [Dx_s] + X' - [Dx_o]. \tag{7}$$

Since we are concerned with systematic effects, we neglect the accidental errors of observation in (x_o). Compared with the ideal of fixed reference stars, an effect

$$-[D\,(x' - x_o)] \tag{8}$$

is therefore introduced in the reduced positions X of the central star. This effect may be written as follows:

$$-t\,[D\mu_x] - P_a\,[D\pi]. \tag{9}$$

The first term represents a uniformly accelerated motion

$$-t\,[D_o\mu_x] - t^2\,[\Delta D\mu_x]. \tag{10}$$

This is, with the opposite sign, the motion of the reference background, consisting of the reflected dependence mean proper motion at the zero epoch, $-[D_o\mu_x]$, and the reflected secular acceleration of this background, amounting to $-2\,[\Delta D\,\mu_x]$ yearly.

The second term represents a uniformly changing annual parallax of the reference stars:

$$-P_a\,[D_o\pi] - P_a t\,[\Delta D\pi]. \tag{11}$$

This is, with the opposite sign, the effect of a uniformly changing annual parallax, consisting of the negative dependence mean parallax at the zero epoch, $-[D_o\pi]$, and the negative yearly secular change of this mean parallax, $-[\Delta D\pi]$.

The apparent secular changes in proper motion and parallax, caused

by the reference stars, may be quite appreciable and may well exceed the true secular changes in these quantities.

4. *Application.*

The most promising star for which measurable values of the secular changes may be expected is Barnard's star ($17^h\,52^m.9$, $+4°\,25'$, 1900); the values of μ, π, and V are large. The relevant data are:

$\mu = 10''.30$ in 356° , yearly change $+''.00123$
$\pi = ''.53$, yearly change $+''.000032$
$V = -110$ km/sec , yearly change $+.0046$ km/sec
$m = 9.7$ mag. , yearly change $-.00013$ mag.

An early study of the secular acceleration was made at the McCormick Observatory.[14] An extensive series of measurements, as yet unpublished, is now in progress at the Sproul Observatory. A set of three reference stars is used; provisional proper motions of these reference stars have been derived by referring them again to a more extended background of some 20 faint stars. Estimates based on magnitude, spectrum, and proper motion have been made for the parallaxes of the reference stars. The relevant data, including the annual dependence changes, are given below:

Reference star	μ_x	μ_y	π	ΔD/yr.
1	$-''.008$	$+''.039$	$+''.006$	$+.0114$
2	$-.011$	$-.006$	$+.04$	$-.0144$
3	$-.016$	$-.031$	$+.005$	$+.0030$

whence we find the following annual changes caused by the reference stars:

acceleration in x: $-2\,[\Delta D\,\mu_x] = -''.00004$
acceleration in y: $-2\,[\Delta D\,\mu_y] = -''.00088$
change in parallax: $-[\Delta D\pi] = +''.00049$.

These figures speak for themselves; they demonstrate the extreme importance of adequate knowledge of the proper motions and parallaxes of reference stars in accurate long-range investigations.

The available material is not yet sufficient to study the secular change in parallax; it does, however, permit a provisional determination of the secular acceleration. The Sproul data include 44 plates from 1916 to 1919, and some 1400 plates covering the interval 1938-1948. In analyzing the positions for proper motion and parallax, an additional term, quadratic in time, was introduced in both right ascension and declination. The coefficients in these terms are half the observed accelerations. The results and other relevant data are given below; the probable errors of the various quantities are about $\pm''.00010$.

Barnard's star	R.A. (x)	Decl. (y)
observed acceleration	$+''.00007$	$+''.00033$
reduction to absolute	$+.00004$	$+.00088$
(observed) absolute acceleration	$+''.00011$	$+''.00121$
(computed) absolute acceleration (1)	$-.00009$	$+.00123$
observed minus computed	$+''.00020$	$-''.00002$

Since most of the proper motion of Barnard's star is in declination, the results in declination are of particular interest. Within the uncertainty of the present data, we conclude that the predicted secular acceleration of Barnard's star is now established by observation. An improved determination will be published at some future time as part of a comprehensive astrometric study of Barnard's star.

REFERENCES

[1] *Astr. Jour.*, **55**, 251, 1951.
[2] *Astr. Jour.*, **52**, 37, 1946.
[3] *Astroph. Jour.*, **113**, 1, 1951.
[4] *Publ. Amer. Astr. Soc.*, **10**, No. 8, 329, 1944.
[5] *Publ. Obs. Michigan*, **8**, No. 1, 1939.
[6] *Astr. Nachr.*, **154**, 67, 1901.
[7] *Vierteljahrschrift*, **37**, 242, 1902.
[8] *Astr. Jour.*, **30**, 137, 1917.
[9] *Nature*, May 2, 661, 1931.
[10] *Bull. Astr. Inst. Neth.*, **6**, 287, 1932.
[11] *Astr. Jour.*, **44**, 73, 1935.
[12] *Astr. Jour.*, **48**, 95, 1939.
[13] *Astr. Jour.*, **52**, 226, 1947.
[14] *Astr. Jour.*, **44**, 74, 1935.

Testing for Cohenite and Schreibersite

By H. H. NININGER

ABSTRACT

It is indicated that the phosphide and carbide of (Fe, Ni, Co) have been sometimes incorrectly identified in the literature on meteorites. A chemical test for the two minerals is described and the results of its application to nearly 300 specimens are tabulated.

Although schreibersite is mentioned in descriptive literature far more frequently than is cohenite, the author finds that the latter proved to be several times more abundant in the meteorites tested than was the former. Photographs and drawings of typical specimens are submitted. A chart showing results of hardness tests reveals the relative hardness of these two minerals and the alloys of nickel-iron in meteorites along side of certain varieties of artificial steel.

For some years I suspected that considerable confusion exists regarding the identity of the carbide and phosphide inclusions in meteorites. Several other writers have also mentioned the probability of such confusion but it seems that no one has seen fit to examine the question critically. We are here presenting the results of a rather extensive application of a well-known test for these two meteoritic minerals on 269 polished sections of the Canyon Diablo irons and a few representatives of other falls. These tests were limited to Xiquipilco, Odessa, Youndegin, Mount Stirling, Leeds, Bear Creak, Seligman (a new find), Seeläsgen, and Arispe.

Farrington, Perry, and others before them, have pointed out that cohenite precipitates copper from an acidulated solution of $CuSO_4$ while schreibersite does not. We decided to apply this test to a number of sections of the Canyon Diablo meteorite to see if our suspicion was correct that much of the "schreibersite" of these famous irons was really cohenite. Perry[1] suggested that cohenite may be more common than is supposed, being sometimes mistaken for schreibersite. But in the same bulletin he states that it is comparatively rare in meteorites. Actually, we found it much more abundant in several well-known

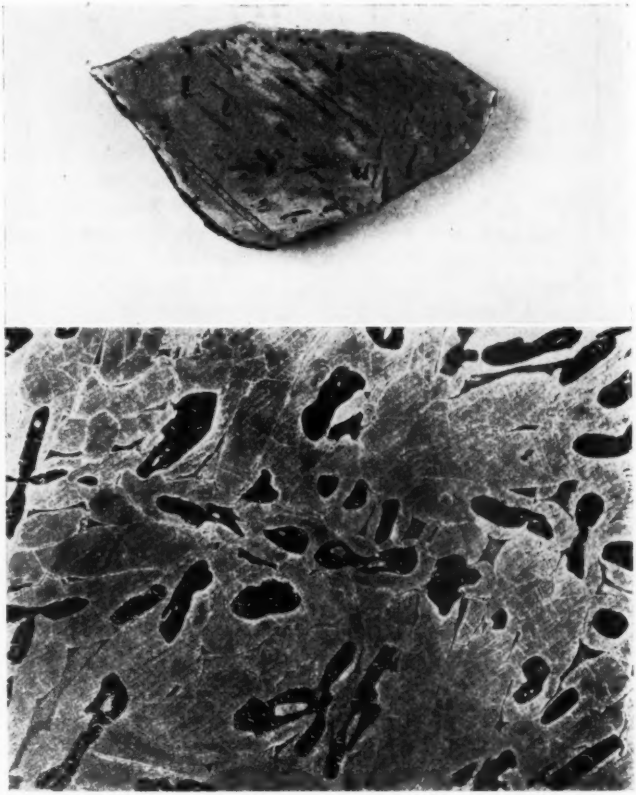

FIGURE 1

1. Section of Canyon Diablo iron showing typical cohenite inclusions and one long straight inclusion of schreibersite at lower left. The axis of this latter is granular schreibersite and the border is a mixture of cohenite and schreibersite; original scale.

2. Typical cohenite inclusions in a Canyon Diablo iron, enlarged × 5¼.

(Both photos by F. K. Dalton)

meteorites than is schreibersite although the latter has been given far more attention in the literature and in some meteorites tested cohenite was the predominant mineral of inclusions even though we did not find it mentioned in the published descriptions.

For example, Merrill[2] in his brief description of the Odessa iron based upon the study of one small section states, "The etched surface is dull and lustreless and abundantly sprinkled with small angular areas of schreibersite," and again, "The entire mass being composed mainly of the broad kamacite plates and their included schreibersite." We examined four sections of the Odessa irons in the American Meteorite Museum with the following results:

TABLE 1

Cat. No. 91C	290 cohenite inclusions	13 schreibersite inclusions
Cat. No. D91.80	27 cohenite inclusions	7 schreibersite inclusions
Cat. No. D91.95	71 cohenite inclusions	0 schreibersite inclusions
Cat. No. 91.42	77 cohenite inclusions	9 schreibersite inclusions.

It is only fair to state that the schreibersite inclusions were on the average larger in size than the cohenite, but when Merrill spoke of the kamacite plates with their included schreibersite he was almost certainly referring to cohenite for that is the manner in which the latter is commonly disposed (See Figs. 1 and 3). The schreibersite is almost never included within kamacite plates but is either between them or interrupts them as angular blocks or irregular nodules (Fig. 2).

When one reads the literature on Canyon Diablo, including some of my own earlier papers, one gains the impression that the principal inclusions are troilite, schreibersite, and graphite. Our tests on 269 irons demonstrate that cohenite is several times more abundant than all of the others. The results on 224 sections are shown below.

TABLE 2

Lots tested	Group 1 Schreibersite only	Group 2 Cohenite and schreibersite	Group 3 Cohenite only	Group 4 Clear of inclusions
63 sections	4	25	22	12
14 sections	4	4	3	3
12 sections	0	2	9	1
9 sections	0	6	1	2
48 sections	0	38	0	10
15 sections	0	5	2	8
56 sections	15	8	15	18
7 sections	0	5	0	2
224 sections	23	93	52	56

Remarks: In Group 2, Lot 1, ratio of cohenite to schreibersite is about 3.5:1. In Group 3, cohenite is about 13 times as abundant as is schreibersite in Group 1. Lot 5, ratio of cohenite to schreibersite 16:1. In Lot 8, ratio of cohenite to schreibersite 8:1. Conclusions: Cohenite strongly predominated in every lot tested.

Two sections of the Leeds meteorite comprising about 3 sq. in. were tested. One contained mostly schreibersite with some cohenite borders. The inclusions in the other were nearly all cohenite.

FIGURE 2

Portion of slice of Canyon Diablo showing: Two rounded nodules of troilite (one halved) each bordered by schreibersite; the smaller one with 3 extensions of schreibersite. Other schreibersite inclusions are circled by broken line. The many small narrow inclusions conforming to the Widmanstätten pattern are cohenite.

At left are several fissures filled with black oxides. Scale × 1.

FIGURE 3

Typical Section of Odessa Meteorite showing cohenite inclusions within kamacite plates, enlarged × 1.

Eight sections of the Xiquipilco (Toluca) meteorite were tested aggregating about 40 sq. in. In these, schreibersite predominated over cohenite in a ratio of about 3:1. The former occurred in large angular

to irregular nodular inclusions and usually consisted of two distinct zones—a central granular portion enclosed by a border of compact material. The latter was usually pure where it adjoined the central core, while outwardly it was combined with cohenite or taenite. The cohenite inclusions appeared as axes of kamacite plates, in dendritic or clover-leaf-like arrangement either at points where several kamacite plates came together or in unlaminated areas of kamacite.

A slice of the Seelasgen meteorite, 2.5 in. x 1.3 in., was examined. 18 inclusions were present. 17 of these were cohenite.

In general the cohenite tends to conform in arrangement to the Widmanstätten pattern, commonly being embedded in the kamacite along the median axes of the plates. However, it frequently departs from this rule as described in the case of the Xiquipilco and rarely occurs in quite a variety of arrangements. Very commonly, the outer zone of a schreibersite inclusion is mixed with cohenite and frequently the latter grades into the pure form adjacent to the metallic alloys.

We are unable to set down any satisfactory method of distinguishing these two minerals by their appearance in the etched section without the application of a chemical test. However, their mode of occurrence seems to be diagnostic in the great majority of cases.

Occurrences of schreibersite are more variable than are those of cohenite. Some of the varieties to be looked for are as follows: (a) A narrow border enveloping troilite nodules (Fig. 2). The outer part of this layer usually merges into cohenite. (b) In angular blocks the central portions of which are often granular. This may be enveloped in a very distinct compact zone which takes a high polish. As in (a) this may grade indistinguishably into cohenite (Fig. 2, enclosed in broken line). (c) Thin plates or bars sometimes lie between kamacite plates. This form is likely to be confused with taenite but distinguished from the latter by schreibersite's brittleness. (d) Similar thin plates or bars may cut across the kamacite and taenite plates as in Bear Creek, Rodeo, Breece, or Chupaderos (Fig. 4A). (e) Dendritic schreibersite occurs in some irons, notably Arispe. This form has also been encountered in Canyon Diablo and other irons (Fig. 4D, extreme right). Closely related in form are the clusters of rounded grains appearing somewhat like the clover leaf. (f) Rarely this mineral, like carbide, appears as rounded grains aligned along the axes of kamacite plates. (g) The rhabdite form is seen as microscopic needles or in sections as rhombohedral crystals more or less abundant in the kamacite of all irons. (h) Finally, it may appear as irregular nodules of almost any asymmetrical form (Fig. 4, B, C).

Considered together, these two minerals, because of their hardness, stand out conspicuously on any surface that is ground and polished by the use of anchored abrasives, especially if the abrasive is based on a slightly spongy material such as cork, felt, or the ordinary buff wheel. However, if ground on a lap with loose abrasive the granular

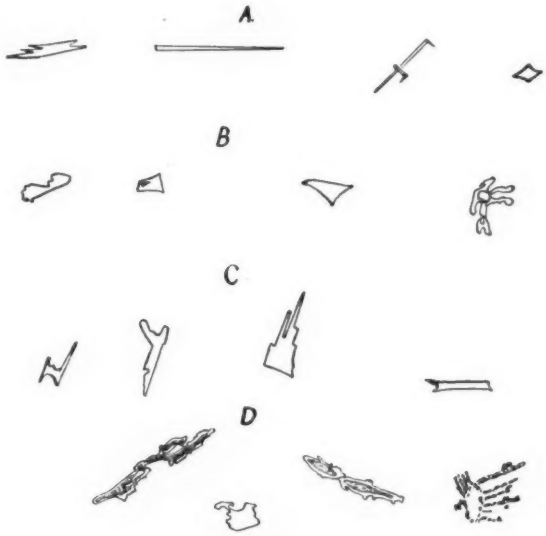

FIGURE 4

Sketches showing wide variation in form of schreibersite inclusions.
A. Four schreibersite inclusions in Bear Creek meteorite.
B. Four schreibersite inclusions in Ponca Creek meteorite.
C. Four schreibersite inclusions in Hualapai meteorite.
D. Three schreibersite inclusions in Canyon Diablo meteorite, two of which show granular centers. Extreme right, dendritic schreibersite from Arispe.

variety of schreibersite will be crumbled away and may appear as a depressed area.

Both are too hard to be scratched by the steel needle. This is usually sufficient to distinguish it from taenite, the only alloy with which it may be confused. But we have found a very great range in hardness for taenite, some of which is also too hard to be scratched with the needle. This alloy, however, has not been found comparable in hardness to the two minerals under consideration and more precise tests for hardness have readily distinguished it (Fig. 5). Taenite may also be distinguished by its elasticity and by its very strong tendency to lie in certain definite arrangements relative to kamacite.[3]

Our technique for the $CuSO_4$ test is rather simple. Use a slightly acidulated 10% solution of $CuSO_4$. Prepare specimens by grinding on 180 to 240 grit silicon carbide. We use the carborundum cloth on a steel sanding wheel with a cork rim to serve as a base for the abrasive cloth. Use care to avoid any oil on the finished surface of specimen, from fingers or other sources. Apply $CuSO_4$ with soft camel's hair brush carefully limiting the solution to the area to be treated. If the nickel-iron does not plate red quickly it may be assumed that the speci-

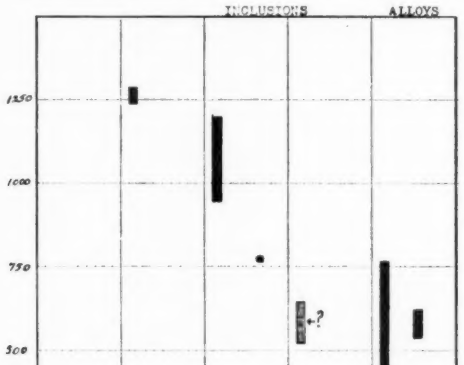

FIGURE 5

HARDNESS TESTS ON METEORITE INCLUSIONS AND ALLOYS (KNOOP SCALE)
· Note: The unidentified inclusion whose hardness is indicated in the 4th column plated gray under the $CuSO_4$ treatment. (The hardness tests here recorded were carried out by F. K. Dalton and associates in collaboration with the author.)

men is not perfectly clean. Sometimes repeated brushing overcomes this. Otherwise, the specimen should be dried and run over the grinding wheel again or else cleansed with alcohol.

When properly applied the solution will give up copper to all of the nickel-iron alloys and to cohenite but not to schreibersite which will remain unchanged. This enables one quickly to discover their identity.

Specimens that have been so treated should be thoroughly re-ground so as to remove all traces of the copper plating. The fact that these have been so treated should be made a matter of record so as to prevent any possibility of copper being later "discovered" in these specimens.

REFERENCES

[1] S. H. Perry—*U. S. Bulletin* 184, p. 23.
[2] Geo. P. Merrill—*Amer. Journal of Science*, Vol. 111, May, 1922.
[3] S. H. Perry—*U. S. Bulletin* 184, pp. 14-15.

BOX 1171, WINSLOW, ARIZONA.

Nubecula: A General Term for a Cloudy-Looking Extragalactic Object

By FREDERICK C. LEONARD

A great deal of confusion has arisen in astronomy, especially in the teaching of the science, thru the use of the term *nebula* to mean two totally different kinds of celestial objects—namely, the so-called *true nebulas*,[1] which occur both in our own Galaxy and in some (probably all) others, and nebulous-appearing *extragalactic objects* or *galaxies*. The word *nebula* is Latin and means "cloud." From the astronomical point of view, a nebula may be formally defined as a cloudy-looking, essentially irresolvable[2] object in interstellar space. The most famous example in the entire sky is the Great Nebula of Orion (known technically as Messier 42 Orionis). A true nebula is in all likelihood a mixture of meteorites, meteoritic dust, and gas, and it may be wholly or partly luminous, or nonluminous.[3] A galaxy, on the other hand, is an organization of stars, nebulas, and (inferentially) every other type of astronomical body, comparable in constitution and structure, if not also in dimensions, to our own Galactic System or Galaxy. The most outstanding example in the northern heavens is the Great Spiral Galaxy of Andromeda (Messier 31 Andromedae). The difference between a true or, as it is often called, a *galactic nebula*, and a galaxy or, as it is sometimes termed, an *extragalactic nebula*, is so obvious and so fundamental as to require no comment other than that it is a most unfortunate circumstance that, even for historical reasons, the same word *nebula* is still applied by some authorities to mean two such entirely dissimilar things as a true nebula on the one hand and a diffuse extragalactic object or a galaxy on the other.

It is therefore proposed that the term *nubecula*[4]—also a Latin word, meaning "cloudlet"—be employed to designate any cloudy-looking, partly or wholly irresolvable[5] object in extragalactic space. There is excellent precedent for the use of the word *nubecula* to mean just this, for the two nearest-known and most conspicuous extragalactic objects, *to wit*, the Greater and Lesser Magellanic Clouds, which are galaxies apparently satellitic to our own, have long been alternatively denominated the *Nubecula Major* and the *Nubecula Minor*, respectively; moreover, according to Webster's unabridged *New International Dictionary*, one of the two astronomical definitions of the word *nubecula* is "a nebula," the other being "the two Magellanic Clouds . . ., called respectively *nubecula major* and *nubecula minor*." Why not, then apply the common noun *nubecula* to designate any cloudy-looking, partly or wholly irresolvable[5] *extragalactic object*, and reserve the term *nebula* to mean exclusively a *true nebula*, either in our own Galaxy or elsewhere in the Universe?

It may be asked, why not call all extended extragalactic objects

galaxies instead of *nubeculas?* The answer is, because not all of these objects are positively known to be galaxies. Whenever an extragalactic object has been proved to be a galaxy, it should, by all means, be so labeled. The more general term *nubecula,* which is entirely descriptive and perfectly noncommittal, may, however, be used to designate any nebulous-appearing extragalactic object, regardless of whether its real nature has been demonstrated or not.

NOTES

[1] Either the English plural, *nebulas,* or the Latin plural, *nebulae,* is permissible. Since the word *nebula* has long been in the vocabulary of the English language, the English plural, *nebulas,* is preferred.

[2] Into stars.

[3] *Cf.* the Websterian definition of a nebula: "One of a large class of celestial structures, of great extension and extreme tenuity, composed of matter in a gaseous or finely divided state."

[4] Either the English plural, *nubeculas,* or the Latin plural, *nubeculae,* may be used; *cf.* n. (1), *ante.*

[5] Into stars *et cetera.*

DEPARTMENT OF ASTRONOMY, UNIVERSITY OF CALIFORNIA, LOS ANGELES
1951 MARCH 12

Mr. Harry B. Rumrill

A Tribute

By NEAL J. HEINES

In the passing away of Mr. Harry B. Rumrill we have lost an ardent devotee to things solar. Not many people are privileged to observe the sun for more than two sunspot cycles. Mr. Rumrill was observing his third. In addition to observing he wrote a number of articles and papers on astronomy which have been published in POPULAR ASTRONOMY; two of them in *Publications of the Astronomical Society of the Pacific*; as also in *Scientia* in both English and French. He was a member of The American Astronomical Society, Astronomical Society of The Pacific, Royal Astronomical Society of Canada, and a Fellow of same, Rittenhouse Astronomical Society, a member of the Executive Committee of the Solar Division of The American Association of Variable Star Observers, and for some years a member of The British Astronomical Association.

He attracted many people within his circle of activities and all have looked upon him with reverence and respect. A man, exact in his rendition, careful in his determination of facts, punctual in his responsibilities, an understanding heart, and one who unconsciously and without special design drew those around him into his friendship circle, and kept them there. Such was this noble heart! His contributions in the field of his choice were many. His devotion outstanding, and, like many who are engaged in scientific endeavor, had a very deep sense of appreciation and understanding of music as well as an accomplished inter-

preter of the compositions of the masters. His was also the privilege of being a devoted husband and father, the revered head of his table, the understanding heart, abundant in compassion, and slow to anger. His eternal reward is evident.

Dr. James C. Bartlett, Jr., of Baltimore, forwarded an expression which bears repetition here. "Still, death must come to all; and when one has led a useful life there need be no regret or sorrow for the dead. I am persuaded with Kipling that 'The Master of All Good Workmen shall set us to work anew'." (*L'Envoi*)

Contributions of the Meteoritical Society

Edited by FREDERICK C. LEONARD
Department of Astronomy, University of California, Los Angeles 24

A Reinvestigation of the Weaver Mountains, Arizona, Meteorite*

EDWARD P. HENDERSON
Associate Curator, Division of Mineralogy & Petrology
and
STUART H. PERRY
Associate in Mineralogy
United States National Museum, Washington 25, D. C.

ABSTRACT

The Weaver Mountains, Arizona, meteorite has been reanalyzed. The new results confirm those of the previously reported analysis of this meteorite. The specific gravity first reported, 7.108, was found to be incorrect; this was redetermined and found to be 8.07. The Weaver Mountains meteorite has similar metallographic structures to the Babb's Mill, Tennessee, and the Shingle Springs, California, meteorites. These 3 meteorites are nickel-rich ataxites, and the groundmass of each consists of imperfectly transformed γ-α structures, in which occur small bodies of kamacite.

Little is known about the history of the meteorite that was found in the Weaver Mountains, near Wickenburg, Maricopa County, Arizona, in 1898. O. C. Farrington[1] gives the weight of the specimen as 38.8 kg., the latitude as N. 33° 58′, and the longitude as W. 112° 35′†. The main mass is now located in the geological collections of the Museum of the University of Arizona, Tucson; and it was thru the kindness of Dr. E. D. McKee that a specimen was obtained for the national collections and thus made available for this study. A reanalysis of the meteorite was made, because experience has shown that often the nickel values reported in old analyses are inaccurate. It was a pleasant surprise to

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†[Hence, the equatorial coördinate number (ECX) = + 1120.340.—ED.]

find that the restudy confirmed the nickel value given in the first analysis by A. Lindner and republished by Farrington.[1]

A sizable sample of the Weaver Mountains meteorite was taken for the reanalysis, because we were interested specially in establishing the phosphorus and sulfur contents of this iron. Phosphorous plays an important and a little-understood role in iron meteorites. The 2 phosphorus minerals commonly found in iron meteorites are schreibersite and rhabdite, and these minerals exert considerable influence on the internal structure of a meteorite.

The sample was dissolved in dilute hydrochloric acid, and the gas that was liberated was passed thru a solution of lead acetate without discoloring it, thus indicating that this iron has no appreciable quantity of sulfur. Schreibersite is insoluble in acid, and, if any quantity of this phosphide had been present, it would have appeared as magnetic grains in the residue. Since the residue was black, was nonmagnetic, and did not have a high specific gravity, it was filtered off and weighed as carbon.

The specific gravity of the Weaver Mountains meteorite was given originally as 7.108, which is definitely below that of most iron meteorites. The redetermined specific gravity is 8.07, which is among the highest of the reported densities for meteoritic irons.

The 6 analyses given in Table 1, *post*, are rather high in cobalt—certainly higher than most octahedrite analyses. This fact suggests that cobalt may increase along with nickel, but, to date, the cobalt values for iron meteorites are not known with sufficient accuracy to warrant paying much attention to this possible relationship. The molecular ratios

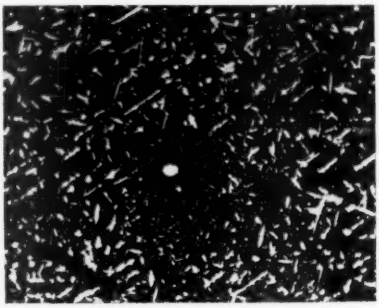

FIG. 1

Typical structure of the Weaver Mountains meteorite, consisting of spindle-like particles of kamacite in a dense groundmass of γ-α aggregate. The larger kamacite inclusions at the center are surrounded by a zone of taenite. The zone surrounding this inclusion is free from kamacite bodies; apparently, these have migrated to, and have been incorporated in, the larger body. A few small rhabdite inclusions were found in this iron, but none is shown in this photograph. A few small, rounded, phosphide bodies were found in a very limited number of these kamacite bodies, but none is shown in this illustration.

Picral, 10 sec.; × 50.

of these analyses agree very well, with the exception of the value 5.16, for (6).

C. Klein[2] correctly classified the Weaver Mountains meteorite as a nickel-rich ataxite, and called attention to its relationship to the Babb's Mill, Tennessee, meteorite which also is a nickel-rich ataxite. The metallographic studies of S. H. Perry[3] show that the Weaver Mountains, Babb's Mill, and Shingle Springs, California, meteorites have similar metallographic structures. The groundmass of each of these irons consists of an imperfectly transformed γ-α structure, thruout which occur numerous small bodies of kamacite. In the Shingle Springs iron, a large proportion of these kamacite bodies contain rounded, drop-like inclusions of phosphide. In the Babb's Mill iron‡ (Troost individual), and in the Weaver Mountains meteorite, these kamacite bodies are essentially free of phosphide inclusions. The phosphorus content of all of these irons is not high enough to be an important factor affecting the metallographic structures.

The reanalysis of the Weaver Mountains iron, together with the

TABLE 1

COMPOSITION OF THE WEAVER MOUNTAINS, BABB'S MILL, AND SHINGLE SPRINGS METEORITES

	Weaver Mtns.		Babb's Mill*		Shingle Springs	
	(1)	(2)	(3)	(4)	(5)	(6)
Fe	80.54%	20.78%	81.45%	81.54%	81.48%	82.21%
Ni	18.03	17.92	17.30	17.74	17.17	16.69
Co	0.91	0.84	1.67	1.26	0.60	0.65
P	0.07	0.12	0.12	0.11	0.31	0.34
S	none	0.15	0.01	.....	0.01	0.05
C	0.035	.....	0.07	.....	0.07	0.03
Mol. Ratio $\frac{Fe}{Ni+Co}$	4.47	4.53	4.52	4.51	4.82	5.16

(1) : new analysis by E. P. Henderson.
(2, 3, 4, 5, & 6) : analyses as quoted by Farrington, *op. cit.*, ref. (1), *post.*

NOTE TO TABLE 1

*There is a possibility that 2 different meteorites are included under the name of Babb's Mill, namely, "Troost's Iron" and "Blake's Iron." Unfortunately, all of these meteorites are not available for restudy. The following 5 analyses of Babb's Mill, taken from Farrington's "Meteorites of North America," pp. 43-4, are republished to show 2 closely matching sets of analyses.

	Babb's Mill				
Fe	88.41%	88.23%	80.59%	81.54%	81.45%
Ni	11.09	11.01	17.10	17.74	17.30
Co	0.66	0.72	2.04	1.26	1.67
S	trace	trace	.....	.....	0.01
P	trace	trace	.....	0.11	0.12
Mol. Ratio $\frac{Fe}{Ni+Co}$	7.94	7.93	4.43	4.51	4.52

‡V. Note to Table 1, *post.*

metallographic studies of the Babb's Mill and Shingle Springs irons, appears to be evidence enough to confirm the analyses reported in Table 1, with the exception of (6), which is apparently as much too high in iron as it is too low in nickel.

A common feature of nickel-rich ataxites containing more than 16% nickel is a well-developed paraeutectoid structure, in which needles and small irregular bodies of kamacite occur either with or without phosphide inclusions in the kamacite bodies.

REFERENCES

[1] "Meteorites of North America," *Mem. Nat. Acad. Sci.*, **13**, 477-8, 1915.
[2] "Mitth. über Meteoriten," *Sitzungsber. Königl. preuss. Akad.*, **32**, 1-6, 1904.
[3] "Metallography of Meteoric Iron," *U. S. Nat. Mus. Bull. 184*, 1944.

The Current Class in Meteoritics at the U.C.L.A.

It may be of interest to report that the current class in meteoritics (Astronomy 118: 3 units: spring semester, 1951) at the University of California, Los Angeles, has an enrolment of 20 students—apparently a record enrolment for this course. Of these 20, 18 are upper-division (most of them 4th-year), and 2 are graduate students. Their major subjects are distributed as follows: mathematics, 6; geology, 5; astrophysics, chemistry, and physics, 2 each; and physical education, psychology, and zoölogy, 1 each. A feature of the course is a (voluntary!) field trip to the Barringer Meteorite Crater of Arizona, scheduled for the spring recess, April 21-28, 1951. In addition to the 20 students in meteoritics (Astronomy 118), one graduate student (major subject, mathematics) is taking the course in special studies in meteoritics (Astronomy 199).

Both the general course in meteoritics and the course in special problems will be offered in the 1951 summer session of the U.C.L.A., to be held during the 8-week period from June 18 to August 11, 1951.—F.C.L.

Geochimica et Cosmochimica Acta

Vol. 1, No. 1, pp. 1-72, 1950, of the forenamed journal, published by Butterworth-Springer, Ltd., 4, 5, 6 Bell Yard, Temple Bar, London, W.C. 2, England, has made its appearance. The "Foreword" (p. 1, quoted herewith in full) states that:

"The aim of this journal is to publish original research papers on geochemistry and cosmochemistry, such as have hitherto been scattered over a wide range of geological, mineralogical, chemical, and astronomical periodicals.

"The chemistry of the Earth and of the Cosmos has become a branch of science independent enough to have a journal of its own. As there should be no political frontiers in science, the editors and publishers hope that the new journal will be used as a means of publication by scientists of all countries.

"The scope of the journal will be wide. Geochemistry as conceived by the pioneers—F. W. Clarke, V. M. Goldschmidt, V. I. Vernadsky—will be its leading theme, but papers from neighboring fields will be welcomed if they have geochemical significance.

"There is a close link between geochemistry and cosmochemistry, and, in this journal, papers dealing with the chemical composition of extra-terrestrial matter, knowledge of which comes mainly from the study of meteorites in the laboratory and [from] the chemical interpretation of spectra, will appear alongside the results from the related geochemical field."

Three (3) of the 8 papers published in this first issue, including the opening paper, are on meteoritical subjects. The number ends (pp. 71-2) with a report on the International Commission on Meteorites, which was appointed by the 18th Session of the International Geological Congress in London, England, in 1948.

The 14th Meeting of the Society, 1951 June 18-20

Attention is called to the notice in *C.M.S., P.A.*, **59**, 156, March, 1951, concerning the 14th Meeting of the Society, which will be held at the University of Southern California, Los Angeles 7, California, 1951 June 18-20.

President of the Society: L. F. BRADY, 922½ Forest Avenue, Tempe, Arizona
Secretary of the Society: JOHN A. RUSSELL, Department of Astronomy, University of Southern California, Los Angeles 7, California

The Planets in June, 1951

By RAYMOND H. WILSON, JR.

NOTE: The time employed is Central Standard Time unless otherwise indicated. The phenomena have been chosen and described for the North American continent, and especially for the United States. The basic data have been taken principally from the *American Ephemeris and Nautical Almanac*.

Sun. The sun will pass the northern summer solstice, that is, its highest northern declination, on June 21 at 11 P.M. It will spend most of the month within a degree of this extreme declination.

Moon. The phases of the moon will occur as follows:

New Moon	June	4	11 A.M.
First Quarter		12	1 P.M.
Full Moon		19	7 A.M.
Last Quarter		26	1 A.M.

The moon will be at perigee on June 19, so that the full moon on that date will be about as bright as ever seen.

An occultation of Regulus will be visible from the eastern half of the United States on June 11, beginning at 7:20 P.M. and ending shortly after 8 P.M.

Evening and Morning Stars. Venus and Saturn will shine in the evening sky; Jupiter in the morning.

Mercury. Mercury may still be visible just before sunrise for the first few days of this month, but will soon disappear to pass conjunction with the sun on June 25.

Venus. Venus will stand at its greatest elongation of over 45 degrees east of the sun on June 25, so that it will be nearly half way to the zenith at sundown.

Mars. Mars will continue so close to the sun as to be practically invisible during this month.

Jupiter. Jupiter will rise at about 1 A.M. and be most favorably placed for observation just before sunrise.

Saturn. Saturn will be near the meridian at sundown, and hence best observed in the early evening.

Uranus. Uranus will be just four degrees south of the two-day moon on the evening of June 6. Later in the month it will be too close to the sun for observation.

Neptune. Neptune will be almost stationary within half a degree west of θ Virginis.

Department of Mathematics, Temple University, Philadelphia, Pa.
April 1, 1951.

Asteroid Notes

By HUGH S. RICE

The following minor planets are the brightest ones available at this time. (1) 3 JUNO, of magnitude 10.1, is at opposition May 26, and is found mostly in western Ophiuchus. Its apparent path is north of ϵ and δ Ophiuchi and μ Serpentis. In fact Juno is in conjunction with δ Oph on May 25, a little after 0^h U.T., and is 20′ north of the star, according to a careful plotting based on the ephemeris. The magnitude is pretty faint, for one of the Big Four and puts the planet beyond the field-glass range; yet it is observable in a small telescope. (2) 14 IRENE, of magnitude 9.2, is at opposition June 6, and is found in southern Ophiuchus. (3) 192 NAUSIKAA, of magnitude 9.4, is at opposition June 18, and is found mostly in northeastern Scorpius (north of the "tail of the scorpion"). (4) 65 CYBELE, of magnitude 10.2, is at opposition July 3, and is found in Sagittarius, south of Scutum.

ASTEROID EPHEMERIDES

0^h U.T. Equinox 1950

	3 JUNO			14 IRENE		
1951	α h m	δ ° ′	1951	α h m	δ ° ′
May 4	16 28.3	— 4 44	May 14	17 18.2	—18 15
14	16 21.1	— 3 57	24	17 9.9	—18 41
24	16 12.9	— 3 18	June 3	16 59.9	—19 9
June 3	16 4.6	— 2 51	13	16 49.7	—19 38
13	15 56.8	— 2 37	23	16 40.5	—20 8
23	15 50.2	— 2 37	July 3	16 33.3	—20 38
July 3	15 45.6	— 2 52			

1951	192 NAUSIKAA α h m	δ ° ′	1951	65 CYBELE α h m	δ ° ′
May 24	18 8.2	—34 18	June 13	19 2.5	—18 10
June 3	17 59.7	—34 42	23	18 55.8	—18 20
13	17 48.6	—34 54	July 3	18 48.2	—18 34
23	17 36.4	—34 48	13	18 40.6	—18 50
July 3	17 24.4	—34 26	23	18 33.7	—19 7
13	17 14.4	—33 50	Aug. 2	18 28.4	—19 25

Hayden Planetarium, American Museum of Natural History, New York, 1951 April 19.

Occultation Predictions for June, 1951

(Taken from the *American Ephemeris*)

The quantities in the columns *a* and *b* are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result in degrees, taking the signs into account, by the quantity under *a* for the star to be observed; similarly, with the latitude, using *b*; apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

Date 1951	Star	Mag.	IMMERSION Greenwich C.T. h m	*a* m	*b* m	Angle E from N °	EMERSION Greenwich C.T. h m	*a* m	*b* m	Angle E from N °
OCCULTATIONS VISIBLE IN LONGITUDE +72° 30′, LATITUDE +42° 30′										
June 11	α Leon	1.3	1 20.5	—0.5	—2.1	135	2 24.6	—0.3	—1.8	291
12	56 Leon	6.0	2 28.7	—0.8	—1.6	96	3 25.4	0.0	—2.2	331
17	CD—23°12133	6.4	3 58.0	—1.2	—2.0	165	4 40.2	—1.6	—0.2	234
23	δ Capr	3.0	4 40.7	—0.9	+1.8	55	5 49.6	—1.4	+1.4	254
OCCULTATIONS VISIBLE IN LONGITUDE +91° 0′, LATITUDE +40° 0′										
June 8	κ Gemi	3.7	1 58.9	+0.7	—2.6	158	2 39.1	—0.4	—0.8	245
10	12 B.Leon	6.3	3 22.7	0.0	—2.0	134	4 19.4	+0.1	—1.5	284
11	α Leon	1.3	1 20.1	0.0	—3.0	170	2 12.7	—1.6	—1.2	263
12	56 Leon	6.0	2 14.2	—1.1	—1.9	123	3 25.4	—0.6	—2.0	311
29	μ Arie	5.7	10 11.5	..	..	352	10 38.6	..	..	305
OCCULTATIONS VISIBLE IN LONGITUDE +98° 0′, LATITUDE +31° 0′										
June 2	47 Arie	5.8	11 16.4	—1.0	—0.1	123	11 44.8	+1.2	+3.5	180
12	56 Leon	6.0	2 26.2	—0.8	—2.5	150	3 36.3	—1.1	—1.6	289
29	μ Arie	5.7	9 47.6	+1.0	+3.2	3	10 23.6	—1.7	+0.2	295
OCCULTATIONS VISIBLE IN LONGITUDE +120° 0′, LATITUDE +36° 0′										
June 16	231 G.Virg	6.4	3 46.7	—2.7	+0.8	80	4 41.6	—0.6	—2.0	349
22	η Capr	4.9	12 20.1	+0.1	+2.1	5	13 5.5	—2.6	—1.7	288

Meteor Notes from the American Meteor Society

By CHARLES P. OLIVIER, President

In these Notes will be found the annual report of our Society for 1950, and also the solution of a fireball's orbit which has interest as definitely coming from the Delta Aquarid radiant.

As to the work done in 1950, it is gratifying to see that the total number of observations is more than 50% greater than for 1949. This increase is largely due to the enthusiasm of a group working in Iowa and Missouri. I greatly regret that some observations by observers in the latter state, though known to have been made, are not yet in my hands, so do not appear in our tables. They will, of course, be credited in a supplemental report along with any others, late in arriving.

We have 15 observers reporting over 300 meteors each. This is a most encouraging thing. However, Charles E. Worley of Ottumwa, Iowa, made the year's record. He is particularly to be commended because all of his meteors were plotted, and all have full data on the record sheets. Few observers in America have ever approximated his 2501 meteors in one year. It is the more remarkable because they were not largely secured on a few shower nights, but represent 81 nights of work. It is obvious from the table that several others did extremely well also. I am sure that when the maps of 1950 are fully studied, many good radiants will be found thereon. It should be noted further that many of our members made preparations for work on shower nights and clouds, etc., ruined their plans.

As for publications, Flower Observatory Reprint No. 79 and No. 84 appeared during the year and have been distributed to members whose observations appeared therein. The first is the most extensive study, so far known, to appear anywhere on telescopic meteors. Our library of papers dealing with meteoric astronomy is constantly growing. We now have 42 bound volumes of papers, sent to me from all over the world, besides the books on the subject published as such. It is believed this collection is perhaps unique, and it has received great commendation from leading authorities in the subject, who have seen it. The A.M.S. works in close cooperation with the Canadian observers, and gladly puts its data at the service of any competent person who is in a position to use them. Fireballs A.M.S. Nos. 2320 and 3549 were fully written up. Radiants Nos. 3058 to 3138, inclusive, were derived and published.

We continue to urge that persons report to us all telescopic meteors, fireballs and long-enduring trains which they may see. The fact that three extensive papers by me have been published dealing with the first and last of these subjects does not mean I am not eagerly gathering data for a further paper on each, which will be prepared when enough have been secured to justify it. The study of long-enduring trains has an added importance as they give us information about the upper atmosphere not only useful to science but also for national defense.

Lastly, we welcome in the A.M.S. as new members persons interested in meteors, if they really intend to take an active part in our work. Information as to how to join will be gladly furnished on request. We do *not* furnish free maps, blanks, etc., to non-members as, unfortunately, has been published in certain places, but without any authorization. Some members have not paid their 1951 dues: will they please do so without further delay.

In the table under "Nights" is recorded the number of nights on which an observer actually worked at least one hour. Those dates on which less than 60 minutes of observations were made are omitted. Were these included the number

would increase considerably. In "Remarks," C means that the meteors were counted only, D that they were described, P that they were plotted and fully entered on the record sheets. As for fireballs, those recorded in routine observations are, in general, not included in the 138 mentioned. Many of these 138 have observations by two or more persons, so the total number of reports upon them approximates fully 200.

TELESCOPIC METEORS IN 1950

Cain, C. C., Minneapolis, Minn.	7	
Cooke, S. R. B., Robbinsdale, Minn.	5	
Fernald, C. F., Wilton, Maine	81	
Johnson, L. T., La Plata, Md.	61	
Oravec, E. G., New York, N. Y.	8	(1948)
Oravec, E. G., New York, N. Y.	6	(1950)
Pearce, R. E., Indianapolis, Ind.	9	
Penhallow, Wm., Woonsocket, R. I.	15	
7 observers with less than 4 each	14	
Total . . .	206	

TABLE

Observer and Station	Nights	Meteors	Remarks
Adams, Tom, Pacific, Franklin Co., Missouri	11	559	C, P
Anderson, Russell E., Chicago, Illinois	8	318	C
Ayres, C. C., Ottumwa, Iowa	42	753	C, P
Bissette, Bill, Wilson, North Carolina	18	154	C, P
Braswell, D. K., Wilson, North Carolina	2	38	C, P
Burlinson, Mr. and Mrs. M. A., Tucson, Arizona	1	48	C
Burns, H. A., Spring Valley, New York	7	185	C, P
Burt, Philip, Memphis, Tennessee	3	20	C, P
Darling, Birt, Lansing, Michigan	5	166	C, P
Dole, Robert M., Cape Elizabeth, Maine	20	526	C, P
Dupee, D. S., Strafford, Bow Lake, New Hampshire	3	211	C
Eason, Mr. and Mrs. F. B., Wilson, North Carolina	4	42	C, P
Eighme, M., Ottumwa, Iowa	20	450	C
Friton, E. E., Webster Groves, Missouri	2	435	C, P; 5 obs.
Gentry, William, Elizabethton, Tennessee	12	170	C, P
Graham, Julian, Salem, Oregon	1	87	C
Green, R. G., Ipswich, Massachusetts	3	44	C, P; 2 obs.
Greene, Robert, Arlington, Virginia	3	45	C
Griffin, Paul E., Phoenix, Arizona	1	28	C
Hay, A. A., Dearborn Observatory, Evanston, Illinois	1	35	C; 4 obs.
Jekel, James, Pacific, Missouri	27	864	C, P
Kendrick, Edith J., Phoenix, Arizona	1	23	C
Keysor, F. A., La Grange Park, Illinois	5	22	C, P
Khan, Mohd. A. R., Begumpet, Deccan, India	66	515	C, P
Knowles, Jeremy H., Marblehead, Massachusetts	15	377	C, P
Komaki, K., Japan	1	28	C
Lee, Roy R., West Allis, Wisconsin	2	100	C; 2 obs.
Naylor, Charles D., Norristown, Pennsylvania	7	123	C, P
Olivier, Charles P., Flower Obs., Upper Darby, Pa.	1	22	C, P
Olivier, Mrs. Charles P., Flower Obs., Upper Darby, Pa.	1	23	C
Oravec, Edward G., New York, New York	1	98	C
Paulton, Edgar M., Brooklyn, New York	6	65	C, P
Peabody, John S., Elgin, Illinois	4	44	C, P
Pearcy, Robert E., Indianapolis, Indiana	1	6	C
Pearlmutter, Arthur, New York, New York	27	930	C, P
Pruett, J., Eugene, Oregon	6	481	C; 3 obs.
Richardson, T., Ardmore, Oklahoma	7	936	C, P; 3 obs.
Rosengarten, G., Gaspe, Quebec, Canada	2	328	C, P

Observer and Station	Nights	Meteors	Remarks
Roat, Evelyn C., Bonita, Arizona	1	31	C
Scott, Thomas, Nauvoo, Alabama	3	57	C, P
Skinner, Gerald B., Brockton, Massachusetts	23	88	C, P
Smith College Observatory, Nantucket Island, Mass.	4	584	C, P; 10 obs.
Strayhorn, Donald, Wilmington, North Carolina	11	140	C, P
Webster, Charles, Wilson, North Carolina	4	81	C; 5 obs.
Weitzenhoffer, Kenneth, New York, New York	2	91	C
Wildman, E. E., Pocono Manor, Pa.	1	60	C
Worley, Charles, Ottumwa, Iowa	81	2501	C, P
Observers with less than 20 observations		48	
Totals	467	12,980	
Telescopic meteors		206	
Fireballs		138	
		13,324	

North Carolina Fireball of 1948 July 26

On this date at 9:36 E.S.T., a beautiful fireball crossed much of the state of North Carolina and apparently ended just over the border of Tennessee.

Our regional director for North Carolina, F. B. Eason of Wilson, North Carolina, at once consulted local papers, asking for reports on this object. Thanks to his efforts, about a dozen persons sent in data, besides several quoted in clippings from newspapers. I regret to say that, as usual, these latter are so lacking in detail as to be almost valueless.

My first inspection of the reports somewhat discouraged me, but after a little study, it seemed that some sort of a solution might be possible. Further work not only confirmed this but eventually I was able to get a solution in which I have considerable confidence. That this could be done was largely due to the report from Dawes Seagraves of Apex, (4). He is a member of the A.M.S. and sent in Bulletin No. 16 quite fully made out. His statement was that it started in the middle of Corona Borealis and ended in Coma Berenices at an altitude of 10°. Using our large globe I deduced $a_1 = 88°$, $h_1 = 62°$, $a_2 = 110°$, $h_2 = 10°$. Next W. B. Smith stated that it ended "just under Ursa Major." He was at Stanley, (6). I deduce $a_2 = 149°$, $h_2 = 21°$. At Wrightsville Beach, (1), Mrs. Armistead Gill saw it disappear just over (or into) the Sound which is west of the hotel where she was. This limits h_2 to $< 3°$. W. H. Bissett at Halifax (2) gives $h_1 = 25°$, h_2 at horizon, but evidently not 90° from zenith due to local obstructions. F. A. Williams at Fairmont (5) saw it move from north on a W-S-W course falling at a 45° angle, but not reaching horizon. G. H. Church at Newton (2) saw it first in east at about a 45° angle. Mrs. H. H. Beams, Goldsboro (8), saw the path in general appearing low from south to north.

Using a large auto map, it was at once apparent that the path ran roughly towards the west-north-west. Several trials were made, and various approximations. Each turned out a little better than the former, and the table gives my conclusions. The beginning height given depends only on (2) and (4) with (6) as a rough check. The end height depends on (4) and (6) only; (1) and (5) being used as rough checks. After I had finished the atmospheric path and transferred it to the globe, it was at once apparent that the object was from the Delta Aquarid radiant. The following table gives the usual data:

Date	1948 July 26.61 G.M.T. = 27.11 G.C.T.
Sidereal time at end point	262°
Began over	$\lambda = 79° 23'$ $\phi = 35° 43'$ at 87 ± 3 km.
Ended over	$\lambda = 81° 58'$ $\phi = 36° 28'$ at 58 ± 0 km.
Length of path	248 km.
Projected length of path	246 km.
Duration	??
Velocity	low
Radiant (uncorrected)	$a = 290°$, $h = 6.7°$
Zenith correction (parabolic)	Δh —1°.5
Radiant (corrected)	$a = 290°$, $h = 5°.2$, $\alpha = 335°$, $\delta = -13°$

This is A.M.S. No. 2322, with orbital elements as follows:

i	12°
☊	304°
π	282°
q	0.037 A.U.

From the various descriptions it seemed to have had a short, following tail (of fragments?) which gave a variety of colors. One observer (5) states positively that the head itself was orange, several indicate that it had a definite disk, (4) says half the size of the Moon. No explosion was seen. Not until the globe was used did I realize that the Delta Aquarid radiant was above the horizon. I was naturally pleased to find the derived radiant fitted this excellently, for the date coincided with the annual appearance of this shower.

In my earlier publications, M_1, M_2, and M_3, can be found a number of orbits computed for this stream. Their general characteristics are rather small inclination, direct motion, and very small perihelion distance. The fireball's orbit agrees well in all these respects. So far, I believe, no periodic comet has been found whose orbit is similar and which could be connected with this stream.

Sincere appreciation is expressed to each of the persons who kindly furnished observations, and most of all to F. B. Eason through whose efforts these persons were consulted and induced to report. He has done very much to increase interest in meteoric astronomy in his and neighboring states.

New Members: The following is a list of names and addresses of persons who have joined the A.M.S. since our last list was printed in Meteor Notes for May, 1950.

Adams, T., 435 Gill St., Kirkwood 22, Mo.
Anderer, J. A., 7929 S. Loomis Blvd., Chicago, Ill.
Anderson, Dr. E. C., 3298 A Gold St., Los Alamos, N. M.
Brewer, E. M., 5218 Morningside Ave., Dallas 6, Texas
Cohn, T., 565A W. Grand Ave., Oakland 12, California
Hovey, B. E., Box 98, R. 2, Huntington, W. Va.
Jekel, J., 130 E. Bodley St., Kirkwood 22, Mo.
McEntire, A., Box 126, R. 1, Old Fort, N. C.
Moran, S., 500 St. Johns Place, Brooklyn 16, N. Y.
Nichols, D., Highland Ave., Glenshaw, Pa.
Pearlmutter, A., 8525 Leffert Blvd., Richmond Hill 18, N. Y.
Rather, J. D., Jr., 64 S. Crest Rd., Chattanooga, Tenn.
Stetson, T. R., 155 Marsh St., Belmont, Mass.

Flower Observatory of the University of Pennsylvania, Upper Darby, Pa.
1951 April 7.

VARIABLE STARS

Variable Star Notes from the American Association of Variable Star Observers

By MARGARET W. MAYALL, Recorder

Miscellaneous Notes on the Variables.

0010*32* S Scl. A well observed maximum the last of December.

001046 X And. During January the star was observed to rise from 14 to 9.5 magnitude.

001726 T And. A 9th magnitude maximum occurred the last of January.

0018*62* S Tuc. A still-stand was observed on the decreasing branch of the light curve in the middle of September. The variable rose to 9.5 magnitude the last of February.

0019*09* S Cet. A 9th magnitude maximum was well observed in the middle of December, a magnitude fainter than the preceding one.

0024*38*a T Scl. A shallow minimum was observed the last of November, following the still-stand in October.

004746a RV Cas. A bright maximum, about 9th magnitude, occurred the last of January.

0134*18* UV Cet. The "flare" star. No maximum has been observed since December 11.

021558 S Per. An 11th magnitude minimum was observed the last of May, 1950. On the first of April, 1951, it had increased to 8.5 magnitude.

0228*13* U Cet. Another broad 8th magnitude maximum was observed in January.

0257*51* T Hor. An 8th magnitude maximum was reached in January, following two fainter ones in 1949 and 1950.

033362 U Cam. A rise from about 8.5 to 7.5 magnitude was observed from January to March.

043208 RX Tau. A faint, 11th magnitude maximum was observed in the middle of October.

0432*63* R Ret. A bright maximum, nearly 7th magnitude, occurred the first of the year, following 3 fainter ones.

0508*48* S Pic. A faint maximum, below 9th magnitude, in December, followed one brighter than 8 in 1949.

0530*05*a T Ori. This erratic "nebular" variable has shown much activity during the past winter. Many rapid fluctuations were observed, as well as some longer ones.

053268 Zinner 402. This star, rediscovered by Robert Greenley, seems to show some evidence of periodicity, perhaps of the order of 75 to 100 days. It is hoped that observers will estimate its brightness when they are observing S Camelopardalis. Zinner 402 is 1'.5 north following the 10.7 comparison star of 053068 S Camelopardalis.

053326 RR Tau. This highly erratic variable has been well observed for the last 500 days, especially during the past winter. It is a star that deserves close attention.

054319 SU Tau. This R Cor Bor type variable has had no real decrease in brightness since the drop of about one magnitude in February, 1946.

060547 SS Aur. Continues to be highly irregular. Maxima were observed

on J.D. 2,433,678 and 712, only 34 days apart, instead of the mean frequency of 54 days.

063462 RR Pic. This nova of 1925 remains almost constant at magnitude 10.9. It has decreased about 0.2 magnitude since 1946.

070122a R Gem. A maximum somewhat brighter than 7th magnitude was observed in January.

072811 T CMi. A 15th magnitude minimum was observed the middle of January.

074241 W Pup. A faint maximum (9th magnitude) in January, followed the deep minimum in the middle of November. The most recently observed minimum, in March, also seems to be a deep one.

074922 U Gem. A maximum was observed for this SS Cygni type variable on about J.D. 2,433,695.

080322 RU Pup. This irregular variable has had almost constant light (8.4 magnitude) for over two years.

080362 SU UMa. A very well observed 11 magnitude maximum occurred on J.D. 2,433,716.

080835 CP Pup. Nova Puppis 1942. This is another slow nova which has remained at constant light, at magnitude 10.8, since 1946.

081473 Z Cam. This star, for which its type of variation is named, continues to vary, with maxima at intervals of 20 to 30 days. (See light curve for 1938-1950 in *P. A.*, **58**, 358, August, 1950.)

082476 R Cha. A faint maximum, about 9.5 magnitude, was observed the last of December. This follows an 8th magnitude one a year ago.

092720 AB Leo. This RU Tauri type variable shows extremely interesting variations, but many more observations are needed of it.

123961 S UMa. This long-period variable with an Se spectrum is very well observed. It showed a marked still-stand before the last maximum in the latter part of October.

142205 RS Vir. A faint maximum at 9th magnitude was observed in the middle of March.

145971 S Aps. This R Cor Bor type variable has remained nearly constant at about 10.5 magnitude for more than 300 days.

151520 S Lib. A deep minimum, near 13th magnitude, was observed in the middle of March. The last preceding minimum was about 11th magnitude the first of September.

154428 R CrB. Nearly constant at about 6th magnitude for more than a year.

155526 T CrB. This recurrent nova (1866 and 1946) has had fluctuations of about half a magnitude around the mean of 10th magnitude during the last 2 years.

174162 W Pav. A faint maximum, nearly 10th magnitude, was observed early in December. Other maxima since 1947 have been 9th magnitude or brighter.

174406 RS Oph. Nova Ophiuchi, another recurrent nova (1901 and 1933), has been showing rapid fluctuations of more than a magnitude amplitude.

184300 V603 Aql. Nova Aquilae 1918 has apparently settled down to about the 11.5 magnitude, with some small fluctuations.

191033 RY Sgr. Another R Cor Bor type star has remained at maximum brightness for more than 2 years.

192745 AF Cyg. An interesting semi-regular variable, similar to Z UMa. Since August it has shown a period of a little less than 100 days, but during the two preceding years it was double that.

210382 X Cep. A 9.5 magnitude maximum was observed the last of December, 2 magnitudes brighter than the preceding maximum.

Observations received during March, 1951. A total of 2,859 observations was received during the month from the following 47 observers:

Observer	No. Var.	No. Ests.	Observer	No. Var.	No. Ests.
Adams	44	74	de Kock	103	530
Ahnert	13	15	Lacchini	22	25
Ancarani	12	16	LeVaux	152	158
Armfield	1	1	Melville	11	24
Boutell	2	22	Mielke	14	30
Buckstaff	7	7	Miller	21	21
Cain	2	2	Morrisby	7	11
Cisler	1	1	Motley	20	37
Cobb	5	10	Oravec	54	117
Cragg	101	105	O'Sullivan	13	26
Darsenius	6	6	Pearcy	17	17
Diedrich, DeL.	1	3	Peltier	50	160
Diedrich, G.	4	7	Pohl	12	34
Domke	16	89	Renner	95	109
Estremadoyro, V. A.	7	7	Rosebrugh	15	52
Fernald	138	228	Schulte	6	9
Ficonetti	12	19	Sofronijewitsch	26	230
Ford	25	25	Taboada	78	85
Galbraith	36	106	Tarwater	13	38
Greenley	81	173	Venter	23	56
Hartmann	100	101	Weber	18	18
Henderson	3	3	Whitehill	3	3
Jerabek	3	5	—		—
Kelly	11	14	47	totals	2,859
Knowles	25	30			

Nova Search. Nova Search reports were received during March from 14 observers, as follows:

Observer	Area	No. Nights	Mag.	Observer	Area	No. Nights	Mag.
Adams, R. M.	31, 32, 33, 34	3	8	**Noseworthy, T.	82	9	6
	53, 54, 65, 66	1	7	*Rick, L.	Dome	3	1
**DeKinder, F.	36	7	8		18	4	4
*Diedrich, DeL.	Dome	2	1		65	3	4
	94	3	6	Rosebrugh, D. W.	Dome	2	3
*Diedrich, G.	Dome	2	2		Dome	1	2
	Dome	2	1	Smith, F. W.	3, 4	6	6
	56	3	6	Venter, S. C.	135, 136, 137	1	5
**Milton, E.	46	5	6	**Williamson, I.	79	4	6
**Morgan, F. P.	34	3	6	**Wright, Mrs. G.	35	2	6
				**Zackon, B.	92	3	6

*Member of the Black River Astronomical Society.

**Member of the Montreal Center of the Royal Astronomical Society of Canada.

April 16, 1951.

Comet Notes

By G. VAN BIESBROECK

Among the faint comets under observation at this time two can be reached with medium-sized instruments but both are fading.

COMET 1950 *b* (MINKOWSKI) has now passed its maximum brightness. On April 6 the total magnitude was estimated here as 10.5 on the Harvard scale. The comet appeared as a round fuzzy spot without indication of tail but the observation was difficult at a southern declination of 29 degrees. From now on the motion is northward so that the object will be better placed for northern observers. However it loses in brightness as it moves into the evening. This very distant comet will probably be followed quite a while with larger telescopes. The continuation of Bobone's ephemeris is as follows:

1951	α h m	δ ° ′	Mag.
May 4	9 43.0	−19 50	9.7
14	30.4	17 18	10.0
24	22.3	15 20	10.2
June 3	17.6	13 51	10.5
13	9 15.4	−12 48	10.7

But the actual magnitude is at least one magnitude fainter.

COMET 1951 *a* (PAJDUSAKOVA). From an arc covering 23 days J. Brady of Berkeley (Cal.) has computed the improved parabolic orbit:

Perihelion time	1951 Jan. 30.42568 U.T.	
Node to perihelion	68°60264	1951.0
Longitude of node	310.52908	
Inclination	87.89231	
Perihelion distance	0.7191404 A.U.	

which gives the ephemeris:

1951	α h m	δ ° ′	Mag.
May 4	6 53.1	+30 55	13.8
9	7 2.3	29 5	14.1
14	10.8	27 25	14.4
24	26.0	24 29	14.9
June 3	39.7	21 56	15.4
13	7 52.2	+19 41	15.8

showing that the object will lose in brightness while advancing towards sunset. When last seen here, April 6, the total magnitude was estimated as 11, which is near the ephemeris value computed on the assumption of a decrease in intensity proportional to the fourth power of the distance to the sun. The comet still showed a short tail in position-angle 70°.

No further data have become available about the several faint periodic comets that can be observed at present. COMET 1951 *b* (AREND-RIGAUX) has faded more rapidly than expected. It was missed on plates exposed here April 3 showing objects as faint as 15^m. Perhaps when an improved orbit becomes available it will be possible to locate it yet by longer exposures.

Williams Bay, Wis., April 10, 1951.

Communications and Comments

Under this heading we shall publish from time to time such material as does not properly fall under any of the established headings of this journal. Here, too, may be found, when occasion arises, articles which the editor may not be willing to give sanction to but which, nevertheless, may be provocative of thought along new lines.

Leveling Effect of Land-Tide on Earth and Moon

Erosion on the earth is caused by the action of water, temperature changes, chemical action,* wind and a number of lesser factors. How great have the forces of land-tide been in aiding erosion on earth?

A man in a boat in a locality where there is a six-foot tide realizes that he is six feet farther from the center of the earth at high tide than at low tide. He knows that the crest of the water-tide wave lags about an hour behind the moon; that the tidal wave encompasses half of the circumference of the earth and that there is a high tide on the opposite side of the earth when he is experiencing a high tide.

A man standing on the ground at the equator similarly rises and falls one foot every twelve hours. The land tide does not lag behind the moon and the land-wave also encompasses half the circumference of the earth. In the vicinity of San Francisco, his rise and fall is about 9 inches—at the poles it is zero.

This motion is slight, but it is exerted laterally as well as vertically. Possibly the elasticity of the crust of the earth is sufficient to absorb this distortion, but some of its brittle components may crack. Regarded from the scale of geologic time and molecular size the motion might resemble a vibration which may have had a significant role in the scheme of erosion on earth.

The situation on the moon may be quite different. The principal causes of erosion are absent.

The land-tide on the moon is approximately 100 feet at the point nearest us. A 100-foot tide on such a small sphere would have proportionately greater effect than on a sphere with lesser curvature. It is also possible that formerly the moon revolved rapidly on its axis. The accumulation of these factors would greatly hasten a shaking-down action of the early crater rims.

Assuming that the craters on the moon are all of meteoritic origin they can be classified as, 1. Indistinct, or almost obliterated; 2. Craters with sharp edges showing no effects of shaking; 3. Intermediate forms.

Thus the rims that have become almost obliterated may represent impacts received when the moon was independently spinning. The land-tide acting like a brake slowed the rotation of the moon and the intermediately flattened rims resulted. The sharp-rimmed craters are the result of post-spinning impacts.

The possibility that the moon or earth received accretions radially symmetri-

*Dr. Eliot Blackwelder in the *Journal of Geology*, 1925, 793-806, reviewed the process of exfoliation. He logically dismisses seasonal and diurnal changes of temperature and colloidal absorption as factors, attributing hydration as the true cause. He demonstrates that absorption of water, CO_2, and oxygen cause an increase in volume which disrupts rocks. He found that exfoliation occurs more commonly in the tropics and underground where temperature changes are negligible.

Dr. D. T. Griggs, in the same journal, 1936, 783-796, carried on laboratory experiments which represented 244 years of daily changes from 32 degrees C. to 142 degrees C. Microscopical examination of prepared sections of the rock showed no changes.

cal in mass is remote. The moon came to a rocking halt with the side facing us which had fortuitously received the greatest mass of meteoritic material. The far side of the moon might be expected to have fewer or smaller craters than the visible side. The land-tide of the earth will eventually halt its rotation with its heaviest side facing the moon.

CHAPMAN GRANT.

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Nova Herculis 1934

December 14, 1934, is the recorded date of the discovery of Nova Herculis 1934. In POPULAR ASTRONOMY, **43**, *93, Dr. Dean B. McLaughlin raises the question whether this star was observed at its maximum. The writer of the following note intimated in a letter a few months ago that he had observed the star when it was definitely brighter than indicated in the reports immediately following the discovery. At our request he has described his observations in detail. We present his report here at this late date for the sake of the record.* EDITOR.

While returning home one evening, a few days before Christmas in 1934, in the sierras of Durango some 100 kilometers west of the city of Torreon, Coahuila, Mexico, a bright star in the western sky attracted my attention. It was still daylight but the sun had already set. The sky was overcast except in the part where the star appeared. I was returning after a visit to a friend in the small village of San Diego. We were both shipping ore from mines in this place. I was anxious to reach the mine house before dark as the trail was very rough and steep. While resting a while for breath I happened to turn toward the western sky-line. The star was so bright that it attracted my attention as already stated. While living in the plains of northern Coahuila I had often seen Mercury and I at once thought of this planet but how could it appear at so high an altitude unless it was an exceptional case when the planet's elongation was at a maximum. For many years I had been in the habit of scanning the skies in the evenings on the chance of seeing a nova. Some weeks before I had seen Vega, Deneb, and Altair set regularly every evening after dark and I knew that, if Vega was still above the horizon, I would be able to see it. I looked for it and found it a little south of the star and at the same altitude. Now that I could orient myself it became not only interesting but also decidedly exciting. Nova Lyrae I thought to myself for I knew that it could be only a nova. Close by were the stars in the head of the dragon but I knew that they would set long before they became visible. I did not even think about the adjacent constellation of Hercules. Vega was the brightest star in northern sky and the stranger was certainly brighter. It had attracted my attention before I had any idea of seeing a star. Vega had not although I had looked also in that direction. I looked directly above Vega to see if I could locate Deneb. The sky was quite blue there but Deneb being a little more than one magnitude fainter than Vega it was not yet visible. Altair was hidden by clouds as was also Capella in the east. What should I do? I thought of hurrying home and taking the azimuth and altitude of the new star with a transit theodolite so that I could compute its right ascension and declination. From my house I could get a better view but I would have to hurry as the nova and Vega would soon set. I decided it would be better to sit down and carefully watch both stars in order to estimate the magnitude of the new star. Its location I could easily observe and calculate later when I would have more time.

I thought it would be easy to estimate its brightness by comparison with Vega. I had made such comparisons before and concluded that my judgment and sense of color were correct. This time, however, I was sadly disappointed when I tried to estimate how much brighter the nova was than Vega. I could not decide to my satisfaction. My first impression when I thought of Mercury and when I was free from any emotion, was that it was about —1.00 magnitude, comparable with Canopus. After seeing Vega I was naturally quite excited. This star was like a pin point exactly as it would appear in a theodolite by broad daylight. Its blue color was apparent. The nova did not look like a pin point. It was decidedly yellow against the blue sky. In fact I thought for a moment it might possibly be the bright head of a small comet. Was it an illusion that it appeared to have discernable disc? I looked from one to the other for about ten minutes until they finally set. For the brightness of the nova I decided on a magnitude of minus 0.20 with a probable error of plus or minus 0.2. The minimum 0.00 would still make it brighter than Vega, the maximum minus 0.40 would make plenty allowance for the fact that the nova was more conspicuous on account of the yellow color against the blue sky. It would probably have been less conspicuous against a dark night sky. I was not very well satisfied with my estimate, but it was the best that I could do. I did not wish to over-estimate its brightness. Any astronomer, amateur or professional, could still make, I believe, a fair estimate of Nova Herculis by watching Vega, soon after sunset, in the west during December. Then before Deneb becomes visible look for Capella in the East. Imagine how bright this yellow star should become in order to be conspicuous. Its color and brightness would then be about the same as the nova's. Capella that evening would have been high in the sky and just as plainly visible as Vega, and a comparison with the nova would have been I believe easier to make. I have reason to believe that I saw the nova at or near its maximum. No previous report has ever been made from the eastern part of the United States for the simple reason that the nova had not yet become bright enough to be seen in the evening sky. I felt sure that a report would come from one of the western states and was curious to know what magnitude would be given. I was mistaken and disappointed. No report came probably because the cloudy weather extended all over that part of the continent. The clouds continued here for a week and I waited seven days before I saw Vega again. I looked for it soon after sunset with a four-inch transit. I saw also Deneb but no sign of the nova. I concluded that it had faded to at least the third magnitude. Assuming that the nova's decline in brightness was regular during the first part of its light curve it would be easy to estimate graphically its maximum, taking seven hours as the difference in time between mine and the official report made in London. I made one mistake by assuming that the nova was in the constellation Lyra, also a second one in not estimating the distance between the nova and Vega while they were in sight. Also a third one in not rising before daylight to see if Vega was visible on the following morning. However, it would have been hidden by clouds. That morning I motored to Torreon and spoke of my experience with a friend who still remembers the occasion. I went to Torreon the following week and read in *Time* a report on Nova Herculis but no magnitude was given. Two years afterwards its maximum magnitude was given in POPULAR ASTRONOMY as 1.4. I sent a report concerning this, received an unsatisfactory reply and many years after wrote again and received no reply at all. An amateur star-gazer may critize my lack of ability to come to a conclusion with regard to the magnitude of Nova Herculis but he should remember the difficulties, a perfectly clear blue sky where the nova appeared, its yellow color compared with

the bluish Vega and, if I may add, the excitement caused by the appearance of the nova. My first impression minus 1.00 magnitude, before I was sure that it was a nova, may have been more reliable. I repeat it attracted my attention. Allowing 0.40 on account of its color it would still be minus 0.60, two magnitudes brighter than 1.40. It would not be a super-nova but its range of about 14 magnitudes would be greater I believe than any of the other novas seen during this century.

F. A. WEDDE.

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General Notes

Professor J. H. Oort, director of the Leiden Observatory, delivered the Halley lecture on May 1, in the Physical Chemistry Theater in Oxford. Dr. Oort spoke on the subject "The Origin and Development of Comets."

Dr. Mars F. Baumgardt, the well-known amateur astronomer and popularizer of astronomy of Los Angeles, California, died on 1950 November 25, at the age of 60 years. A brief account of Dr. Baumgardt's life and work, by Dinsmore Alter, appears on p. 46 of *The Griffith Observer* for April, 1951.

Professor Antonie Pannekoek, of Zeist, Holland, has been awarded the Gold Medal of the Royal Astronomical Society for his work in astrophysics and on the structure of the galactic system. Professor Pannekoek delivered the George Darwin lecture at a meeting of the Royal Astronomical Society on April 13. His subject was "The Origin of Astronomy."

The Second Annual National Science Fair will be held in St. Louis, May 10, 11, and 12. High school boys and girls from all over the country, winners in local fairs, will enter exhibits in the National fair. It is jointly sponsored by Science Service and local newspapers.

Students from ten states and the District of Columbia will arrive in St. Louis May 10 to set up their scientific exhibits. The exhibits will be judged by a panel of outstanding scientists and awards of scientific equipment and books worth $1,000 will be made to the outstanding students. Each national contestant will receive a Gold and Silver Finalist Medal.

The Spring Meeting of the A.A.V.S.O.

At the invitation of the Reverend Francis Heyden, S.J., of the Georgetown College Observatory, and the National Capital Astronomers, the 40th Annual Spring Meeting of the AAVSO will be held May 11-13, 1951, in Washington, D. C. The program includes a lecture by Dr. John S. Hall of the U. S. Naval Observatory, on "Effects of Scintillation of Stars," a visit to Georgetown Observatory, a visit to the Sterling Field Station of the National Bureau of Standards, and possibly a trip to U. S. Naval Research Laboratory.

Annual Convention of the Western Amateur Astronomers

The Astronomical Society of San Diego and the Amateur Telescope Makers and Astronomical Club wish to announce they will jointly sponsor the Third

Annual Convention of the Western Amateur Astronomers. This convention will be held August 13, 14, and 15, 1951, in San Diego's Balboa Park. A trip to Palomar Observatory is planned.

Those interested are requested to write to Carl W. Dickson, Chairman of the Convention Committee, 6951 Mt. Vernon St., Lemon Grove, California.

Provisional Sunspot Numbers for March, 1951*

1	74	11	40	21	59
2	62	12	61	22	60
3	50	13	43	23	83
4	45	14	36	24	110
5	38	15	26	25	108
6	50	16	31	26	97
7	55	17	26	27	84
8	54	18	26	28	74
9	33	19	38	29	70
10	26	20	49	30	65
				31	52

Mean Value for March
R = 55.6

*From the Zürich Observatory, furnished by Mr. Neal J. Heines.

Synchrocyclotron Nearing Completion

Satisfactory initial tests of the University of Chicago's $2,500,000 synchrocyclotron, giant atom smasher, have been made after three and one-half years spent on design and construction, Samuel K. Allison, director of the University's Institute for Nuclear Studies, announced recently. Deuterons, the nuclei of heavy hydrogen atoms, have been accelerated to an energy of 250 million electron volts, the highest known energy ever achieved artificially with these atomic particles. Herbert L. Anderson, professor of physics in the Institute, and John Marshall, assistant professor, who directed design and construction of the big accelerator, conducted the tests.

Next step in getting the Chicago instrument into final working order will be to produce a focussed beam of protons, the nuclei of ordinary hydrogen. In the test, the deuterons were not brought outside the magnetic field. The energy attained with deuterons indicates the synchrocyclotron will accelerate protons to energies of the order of 450 million electronvolts, making it the most powerful accelerator of positive ions in the western world. Funds for the synchrocyclotron were largely provided by the Office of Naval Research, Department of the Navy, with the balance coming from the University of Chicago Cancer Research Foundation.—(*University of Chicago news release.*)

Astronomical Research now in Progress

According to Dr. Edwin P. Hubble astronomers are now exploring a region of space so vast that it may be a fair sample of the universe itself. From a study of the sample they are attempting to infer the nature of the universe, the Staff Member of the Mount Wilson and Palomar Observatories, operated jointly by the California Institute of Technology and the Carnegie Institution of Washington, told members of the American Philosophical Society at their annual meeting in Philadelphia.

The possibility of this venture emerged a quarter-century ago, he said. At that

time the 100-inch telescope on Mount Wilson broke free from our stellar system—the Milky Way—and suddenly enlarged the observable region of space. Study of this broad realm showed it was inhabited by lonely, drifting swarms of stars called nebulae, star systems like the Milky Way.

Surveys using them as landmarks established two general features of the newly-revealed realm: It is roughly homogeneous, or on a grand scale is very much the same everywhere. And there is a "strange law of the red-shifts," arising from the apparent shift of light from stellar systems to longer-than-normal wave lengths. The phenomenon may be likened to the drop in pitch of a train whistle as the locomotive disappears down the track and the sound waves effectively increase in length. Many observers have interpreted the red-shifts as evidence that the universe is expanding rapidly.

However, Dr. Hubble said, the 100-inch telescope was not powerful enough to determine uniquely the nature of the universe. So the explorations are being repeated with the 200-inch Hale telescope on Palomar. It gathers as much light as a million eyes and could photograph the light of a candle 30,000 miles away. Combined with the 48-inch wide-angle Schmidt reflector, he said, the Hale permits the use of more accurate techniques over a far larger sample of space.

The preliminary problem is to set up an accurate distance scale. As a first step, relatively nearby globular clusters, or compact masses of thousands of stars, will be used to establish the distance of the great spiral nebula known as Messier 31. This will fix the brightness of its Cepheids, certain regularly varying giant stars, and novae, so-called "new stars" which flare into sudden brightness and then fade.

The next step is to use the Cepheids and novae to measure the distance of other nebulae out as far as the Ursa Major Cloud and the Virgo Cluster. These are estimated currently to be about six and eight million light years (or 36- to 48,000,000,000,000,000,000 miles) distant.

This will give astronomers a collection of about a thousand nebulae of all types so that the nebulae themselves can be calibrated as distance indicators. Their average luminosity, variations from the average, and the brightness nebulae in clusters can be used to indicate the distance of more remote clusters.

In this way, Dr. Hubble said, it should be possible to study the distribution of nebulae out to a billion light years and to follow the law of the red-shifts out to perhaps 500 million light years. If the red-shifts, which increase with distance, express the speeds of recession, observers should find that clusters at this distance are receding at about 46,000 miles a second, or one-fourth the speed of light.

Measurement of great distances involves two assumptions, he pointed out. One is that space between the nebulae is essentially transparent. As yet, he said, there is no reason to think it is not. The other assumption involves time. "When we look out into space, we look back into time, far back into the history of the universe. We must compare neighboring nebulae as they were a few million years ago with remote nebulae as they were several hundred million years ago. Since we have no more recent information, we proceed on the assumption that evolutional changes may be ignored, that total luminosities have not altered materially during the time the light requires to reach us."

Exploration with the 200-inch telescope, he said, are aimed at determining accurately the density of matter in space as well as the rate of red-shifts in our neighborhood and at pushing the investigations out to the limits of the instrument to search for systematic changes with distance.

After the observational data are in and a distance scale reliably established—

work expected to take years—astronomers may be able to eliminate theories and reduce the number of possible worlds. It might then be possible, Dr. Hubble said, to identify among the few survivors the specific type that must represent the universe we inhabit.

(A news release from the California Institute of Technology, April 19, 1951.)

Book Reviews

Astronomisches A B C für Jedermann, by Rolf Müller. (Johann Ambrosius Barth, Munich, Germany.)

This paper-bound book of 182 pages is the second edition under this title. The former edition appeared in 1938. In the preface the author states that considerable revision was made necessary by the developments in the intervening twelve years. He also reiterates the statement that this work does not in any sense claim to be a complete account of the science of astronomy. This he says is the province of more extensive treatises. This volume is merely what is suggested by the title. It is an alphabetical arrangement of the numerous terms pertaining to astronomy with a brief definition for each. We may properly describe it as an astronomical dictionary. As in any good dictionary the verbal definitions are supplemented by diagrams and pictures when necessary. The author calls it a handbook for daily use, and such it is. It is in the German language, but, fortunately, scientific terminology is to a large extent international, and one can frequently find an answer to a question even though the answer is given in a foreign language. C.H.G.

Men of Other Planets, by Kenneth Heuer. (Pellegrini and Cudahy, 41 E. 50th Street, New York 22, N. Y. 1951. x + 165 pp. 14.4 x 21.5 cm. $3.)

A "guide-book to the planets, to planetary people and places"—this is the author's aim, inasmuch as we shall be entering an era of interplanetary travel. The point of view is optimistic: while we do not *know* of men of other planets, the author has presented arguments for the possibility, and has given the ideas of some leading thinkers of the past, who have written on the subject. Pervading the book is an undercurrent of philosophy supporting the main theme. Recent tendency seems to defend the probability of life on other worlds. Indeed Fred Hoyle, author of the latest cosmogonic theory, believes there are probably "100 million million" planetary systems altogether in the universe.

Heuer's book is written for the general public and anyone interested in possible extra-terrestrial inhabitants. It differs from Sir Harold Spencer Jones' "Life on Other Worlds" in being more concise, easier to read, and optimistic, in conformity with latest astronomical ideas. "Life on Other Worlds" is much more technical and detailed. The value of Heuer's work is in establishing the overall picture of life possibilities (or impossibilities) on different celestial bodies. Likely no other recent effort is as comprehensive. The supporting evidence is good, and in several instances there are understatements, which show the author's caution.

There is an excellent foreword by Professor Charles H. Smiley of Brown University. The introductory chapter is on interplanetary communication and travel. This is followed by a discussion of the possible presence of life on most all planets. The extraordinary biological adaptation of life-forms on the earth is properly stressed, and its application to other worlds is noted. Succeeding chap-

ters discuss the Lunarians, Venusians, Martians, and others. Considerable general astronomical information is given, thus enhancing the value of the book. If the reader objects to expressions like the last chapter-heading ("Census and Directory"), he will likely abandon the objections upon careful reading of the text.

Heuer's style is quite pleasing. The diction is fine, the words being well chosen, and the whole volume delightful reading. The expression "solar republic" is a nice touch, and "Director of the Solar System" is interesting. On page 23 the author says:

". . . the universe is mystifying and terrifying—even beyond our present understanding. No one knows the terrors of the journey upon which man is about to embark; no one can know until the journey has been made. How many of the first ships will be lost before arriving at their shore, some to drift aimlessly across the ocean [of space] to the end of time, others to be destroyed rudely by secret forces, we dare not venture to say. But undoubtedly the first men to venture into outer space will encounter unknown perils; the solution of space travel will result in countless new problems."

The book is nicely printed on non-glare paper. We note a few cases where a large numeral begins a sentence; this is highly commendable. There is no good reason against it, in spite of the style books. Spelling-out of numbers definitely inhibits the reading; and the data in this form remain buried in the book and cannot be located again easily. In a number of cases the editors have spelled out numbers unnecessarily and inconsistently.

Besides diagrams, there are several, full-page, scratchboard illustrations. These symbolic drawings are very exceptional. The "thinking and talking trees" drawing is quite extreme, but illustrates Flammarion's conception of what might happen if plant evolution proceeded along different lines. In the chapter on Lunarians there is a drawing of the moon's hidden hemisphere. This illustration is about the most interesting, bizarre, and outré picture we have ever found; it bears repeated scrutiny.

One could object to the shortness of "Men of Other Planets," the book being so fascinating as to make one desire a larger volume. We object to the purpose of the book being buried on page 23, to the publisher's arrangement of the contents page, the lack of certain necessary hyphens, and the absence of a list of illustrations. There is no frontispiece or index, both of which should be supplied with every book; and the last 5 pages are unnumbered.

We have not noticed any major errors. We believe Heuer has exaggerated the sun's central pressure, and he claims that space navigation will be conquered when man reaches Pluto, the next journey (to the stars) being "comparatively simple"; this is probably too optimistic. The only misspelled words observed are Mare Tranquillitatis, Mare Vaporum, Albireo, and Epsilon Boötis; but most of these are commonly misspelled even on star charts.

Heuer's work is an important addition to the literature and fulfills a noble purpose.

HUGH S. RICE.

Hayden Planetarium.

Publications Received.—The publishers of POPULAR ASTRONOMY hereby acknowledge receipt of the following named publications and express their great appreciation of the courtesy shown on the part of those who sent them.

Contributions from the Lick Observatory. Series II:

No. 24. "Color Excess, Total Photographic Absorption, and the Distance of the

Dark Cloud in the Aquila Region of the Milky Way," by Harold F. Weaver.

No. 25. "Photoelectric Studies. I. Color-Luminosity Array for Members of the Hyades Cluster," by Olin J. Eggen.

No. 26. "Photoelectric Studies. II. Color-Luminosity Array for Members of the Pleiades Cluster," by Olin J. Eggen.

No. 27. "Photoelectric Studies. III. Color-Luminosity Arrays for the Coma Berenices and Ursa Major Clusters," by Olin J. Eggen.

No. 28. "Radial Velocities, Spectral Types, and Luminosity Classes of 820 Stars," by J. H. Moore and G. F. Paddock.

No. 29. "The Structure of the Wolf-Rayet Eclipsing Variable V 444 Cygni," by Gerald E. Kron and Katherine C. Gordon.

No. 30. "Photoelectric Studies. IV. Color-Luminosity Array for Stars in the Region of the Sun," by Olin J. Eggen.

No. 31. "W. F. Meyer's Work on Beta Canis Majoris," by Otto Struve.

Contributions from the Perkins Observatory:

No. 26. "Neutral Oxygen in Stellar Atmospheres," by P. C. Keenan and J. A. Hynek.

No. 27. "The Spectra of R Andromedae (Maximum) and Mu Cephei between 7400 and 8800 A," by L. H. Aller and P. C. Keenan.

No. 28. "On the Stellar Dynamics of Spherical Galaxies," by J. Belzer, G. Gamow, G. Keller.